HYDROPOWER | WATER MANAGEMENT | ENVIRONMENTAL PROTECTION | INLAND NAVIGATION | ENERGY RECOVERY

ENERGETYKA WODNA

3/2021 (39)
FREE COPY
ISSN 2299-0674

THE FUTURE OF HYDROPOWER – IEA SPECIAL MARKET REPORT

Page 46

HYDROPOWER EUROPE – A ROADMAP FOR EUROPEAN HYDROPOWER SECTOR DEVELOPMENT

Page 12

EUROPEAN GREEN DEAL AND HYDROPOWER

Page 26

DESIGNING HYDROTECHNICAL STRUCTURES IN THE CONTEXT OF UPCOMING EUROCODES CHANGES – PROLOGUE

Page 56

TRMEW

re: respect energy

Thou shalt first respect!

Respect is at the heart of human existence. Respect for both nature and yourself. Due to the lack of this respect, as humanity, we have breached the barrier of sustainable development.
At re:spect energy, we are aware of global problems associated with environmental pollution, so out of respect for nature and out of respect for our clients, we strive to generate only positive energy! As the only company in Poland, we sell 100% green electricity, coming directly and exclusively from renewable sources.
We offer our eco-conscious customers a new quality, attractive terms of cooperation, and innovative solutions. We believe that it is high time for changes, and that is also true for the electricity supply market. Take the first step, respect nature, respect others, respect yourself!

re:spect nature – re:spect yourself!

visit: respect.energy

The task of "Publication a special, fair issue of the quarterly "Energetyka Wodna" in English language version and distribution among participants of international fairs and conferences from the renewable energy and hydropower industry" was co-financed by Minister of Development and Technology.

Polska

FROM **EDITORIAL OFFICE**

The conclusions of the report published by International Panel on Climate Change (abbreviated as IPCC) leave us disillusioned. The increase of the average global air temperature caused by man-made greenhouse gas emissions result in climate changes that are visible in every corner of the globe. Even at the moment of writing this editorial we have to face some extreme weather phenomena – and these are expected to grow in magnitude in the foreseeable future. IPCC experts do not have doubts that some of the changes that have already occurred are irrecoverable – yet there is still chance to avoid making a (nomen-omen) hell-on-Earth out of this planet. It is however necessary to undertake some serious action for decreasing the amount of greenhouse gasses that are emitted into the atmosphere.

One of the methods to decrease CO_2 emissions is to transform the world's energy sector – and it can be done with the significant participation of the hydropower – both, as an energy producer, and a grid-stabiliser. Nonetheless, International Energy Agency (IEA) in its most recent report (Hydropower Special Market Report, Analysis and forecast to 2030) predicts that in the years 2021–2030 the growth of the installed power within hydropower sector shall slow down by nearly 25% as compared to the previous decade, what in turn, would not allow to achieve an ambitious goal of globally reaching zero net emission of greenhouse gasses in 2050.

To turn such a trend around, it is necessary for the governments all over the world to adopt much more ambitious goals in terms of hydropower development while simultaneously reducing formal barriers that hinder a way to quickly complete a hydropower project. For the people interested in the IEA forecasts, I invite them to read the Issue's featured article.

At the level of the European Union, provisions of the European Green Deal shall be of high relevance for the sector, and those are going to be translated into tangible opportunities and risks for hydropower. Therefore, taking into account hydropower specifics, which is not only a zero-emission energy source, but it can also substantially contribute to grid-wide balancing of variable-power renewables, there is a significant chance that hydropower shall become one of the planned changes beneficiaries. The details of the planned influence of European Green Deal on hydropower have been presented by PhD Radosław Maruszkin in the Law section of the magazine.

As a follow-up to that, the results of the Hydropower Europe Forum in the form of R&D agenda and a plan for the technological development of the hydropower sector are available for reading in the Practice section of this issue. The aforementioned publication has been prepared by EngD Jean-Jacques Fry, the chairman of the ICOLD European Club.

When it comes to Polish representatives of the hydropower sector, the most important information of the passing quarter is the enactment of the amendment to the Renewables Act. Thanks to the effort of the Polish Society for the Development of Small Hydropower Plants, SHP objects shall gain two more years of support via Feed-in-Tariff and Feed-in-Premium price-guarantee systems. As it is emphasised by Ewa Malicka, the chairman of the Society, it is a bridging solution devised to enable existing SHPs to operate until new legal framework is introduced, allowing for their further exploitation of these objects.

Moving away from reports and policy, I recommend reading a number of technical articles, where the subject raised are, among others, how to utilise vinyl sheeting when building an underground antifiltration baffle, how to strengthen and seal the riverbed and the embankments of hydroengineering structures while working underwater, description of trademark technological solutions for the planned barrages on the Vistula river, designing hydroengineering structures in the light of changes in Eurocodes or methods for mitigating barriers to European eel migration.

Have a pleasant read!

Michał Kubecki
Editor in Chief

HONORARY PATRONAGE

State Water Holding Polish Waters

MINISTRY OF STATE ASSETS

STRATEGIC PARTNER

renpro

PARTNERS

AQUA TECH

EDO

EKO-ENERGIA MAŁOPOLSKA

IOZE hydro

KO-RO kancelaria brokerska

MAVEL

MEW MAŁE ELEKTROWNIE WODNE GAWLIKOWSKI

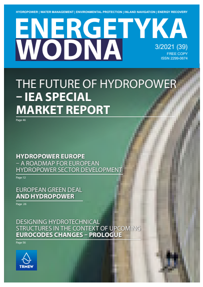
re: respect energy

uponor

WODEL

ENERGETYKA WODNA

INTERNATIONAL QUARTERLY
NO 3/2021 (39) – estimated readership: 2 500 unique recipients
www.energetyka-wodna.pl



NEWS

3 Funding for biogas plants and hydroelectric power plants

4 Creating Kotlarnia retention reservoir in mine excavation

4 The Żelazna polder will be twice as big

5 Modernization in the PGE EO PSPP

6 Overhaul of Myczkowce SHP

8 News from TRMEW

8 Calendar

10 From the World

PRACTICE

12 Hydropower Europe – a roadmap for European hydropower sector development

16 The technology of vinyl sheet piles with gaskets in the construction of cut-off walls

18 Reinforcing and sealing of the bottom and slopes of hydro-engineering structures in underwater conditions

22 Promoting the European small hydropower industry

24 HYDAC – your partner for closed hydropower cooling systems

LAW

26 European Green Deal and hydropower

30 Additional two years of support for SHP is now a reality!

32 Contractors' financial claims related to an extended time of project performance

PROJECTS

34 Characteristic technical solutions of barrages planned on the Vistula River on the International E40 Waterway

44 To efficiently use the potential of Besko Dam

KNOWLEDGE

46 The future of hydropower – IEA Special Market Report

52 Hydropower potential lies also in sewage systems

56 Designing hydrotechnical structures in the context of upcoming Eurocodes changes – prologue

ECOLOGY

62 Evaluation of the effectiveness of methods minimizing the limitations of silver eel migration

EDITORIAL OFFICE:
Michał Kubecki – Editor in Chief
Michał Lis – Managing Editor
Aleksandra Wołowiec – Editor
Dominika Wójtowicz – Editorial Assistant
e-mail: redakcja@energetykawodna.info
mobile: +48 518 304 194

SUBSCRIPTION AND ADVERTISING:
Monika Grzybek
biuro@energetykawodna.info

DTP:
Gustaw Nowak
grafika@energetykawodna.info

PRINTING HOUSE:
Agencja Wydawnicza „ARGI"
ul. Żegiestowska 11
50-542 Wrocław

TRANSLATION:
GROY Translations

PHOTO ON COVER:
Mooserboden dam, Austria,
source: remigiuszagato, Adobe Stock

PUBLISHER:
Polish Association for Small Hydropower Development (TRMEW)
ul. Królowej Jadwigi 1
86-300 Grudziądz
phone: +48 (56) 46 49 644
fax +48 (56) 46 49 643
e-mail: biuro@trmew.pl
www.trmew.pl

TRMEW

Orders for institutional subscription adopts Kolporter Sp. z o.o. Sp.k. Information available at the hotline number 0 801 40 40 44 or on the website www.dp.kolporter.com.pl

It was published: 30.09.2021

FUNDING FOR BIOGAS PLANTS **AND HYDROELECTRIC POWER PLANTS**

Applications for funding for investment projects in renewable energy sources and energy storage devices in the new edition of the Agroenergia programme can now be submitted. Funding will be offered in the form of grants of up to 20% of eligible costs, and in the case of investment projects in an agricultural biogas plant or small hydroelectric power plant also in the form of soft loans.

Source: www.pixabay.com, nattanan23

The call for applications for the Agroenergia programme, which aims to fund investment projects which goal is to increase renewable energy production in the agricultural sector, opened on 20 July. Beneficiaries of the Agroenergia funding may be natural persons who are owners or lessees of agricultural properties, the total area of which is from 1 ha to 300 ha of agricultural land, and who have personally run the farm for at least one year prior to submitting the application. Applications may also be submitted by legal persons who are owners or lessees of agricultural properties, the total area of which is from 1 ha to 300 ha of agricultural land, and who have been engaged in agricultural activities or in the provision of agricultural services for at least one year prior to submitting the application.

This year's edition of the Agroenergia programme has been divided into two parts. In the first part, it will be possible to obtain funds for photovoltaic, wind and heat pump systems with an installed capacity exceeding 10 kW and not exceeding 50 kW, i.e. not exceeding the legal threshold for microgeneration, including hybrid systems and accompanying energy storage facilities.

In the second part, it will be possible to obtain funds for agricultural biogas plants with accompanying systems of agricultural biogas production and hydroelectric power plants with a capacity of no more than 500 kW with accompanying energy storage facilities. The budget of the Agroenergia programme is PLN 200 million, of which PLN 153.4 million can be allocated for grants and PLN 46.6 million for loans. For the first part of the programme, the form of funding will be grants. For the second part of the programme, it will be possible to obtain grants and soft loans, while there will be no obligation to apply for funding in the form of a grant. In the first part of Agroenergia, funding in the form of a grant can cover up to 20% of eligible costs for energy generating systems with a capacity of 10–30 kW (but no more than PLN 15,000), and up to 13% for larger systems with a capacity of 30–50 kW – but no more than PLN 25.000. For projects involving the construction of a hybrid system (photovoltaic system together with a heat pump or a wind turbine together with a heat pump, combined into one system), the maximum funding will be calculated on the basis of the installed capacity of each device separately and also, additional funding of PLN 10.000 is possible to obtain. In order to be awarded funding for energy storage facilities, it must be integrated with an energy source that will be implemented in parallel as part of the project. Funding for energy storage facility can cover up to 20% of eligible costs, while the eligible cost of such a device cannot exceed 50% of the cost of the generation.

The second part of the programme, covering investments in agricultural biogas plants and small hydroelectric power plants, offers funding in the form of a loan of up to 100% of eligible costs. The interest rate on the loan may be lenient (WIBOR 3M + 50 pb, not less than 1.5% per annum) or may be set as below-market. On the other hand, funding in the form of a grant may amount to 50% of the eligible costs, but not more than PLN 1.8 million for sources with a capacity of up to 150 kW, PLN 2.2 million for sources with a capacity of 150–300 kW, and cannot exceed the amount of PLN 2.5 million if the investor applies for support for the construction of systems with a capacity of 300–500 kW. In addition, this part provides for funding in the form of a grant of up to 20% of eligible costs for accompanying energy storage facilities. The funding will be in the form of a refund awarded upon the completion of the investment project. Eligible costs may include fixed assets and equipment – purchase, assembly and commissioning of the systems covered by the project, while the purchase of fixed assets financed through leasing, the cost of VAT and the cost of an energy audit are not eligible. The period of eligibility of costs was set from 1 June of the current year to mid-2027. However, the project cannot be commenced before the submission of the application for funding. The commencement of the project should be understood as the order or purchase of equipment, as well as conclusion of a contract for its installation or ordering its installation in another form. The Agroenergy programme is expected to run until 2027, with contract signing to be completed by 31 December 2025.

GRAMWZIELONE.PL

Editorial office gramwzielone.pl

CREATING KOTLARNIA RETENTION **RESERVOIR IN MINE EXCAVATION**

State Water Holding Polish Waters Regional Water Management Board in Gliwice, the communes of Bierawa and Kuźnia Raciborska, State Forests – Regional State Forest Directorate in Katowice, Kopalnia Piasku Kotlarnia S.A. in Kuźnia Raciborska signed a Letter of Intent concerning the creation of the Kotlarnia reservoir.

The planned hydraulic facility on the Bierawka River in the Bierawa commune will be built in a former mine excavation. It is an example of the reclamation of a mining area. This solution does not entail significant interference in the natural environment but it allows for obtaining numerous benefits. The reservoir will have a retention function, it will counteract the effects of flooding and drought. It will be constructed as a wet, water-filled reservoir and its many functions will include flood control, which will relieve the Bierawka catchment area in the event of rising water levels. The construction of the wet reservoir may also have a positive impact on hydrographic conditions in the area. As a result of sand mining carried out since the 1960s, the post-mining area in Kotlarnia is now a depression funnel, which has disturbed hydrographic conditions in the area and results, among other things, in the drying out of the surrounding forests – editor's note.

The basin will be a water reservoir that will address many needs of local residents. Due to the development of the area around the reservoir, it will become a place for recreation and rest. This will undoubtedly benefit communes whose attractiveness will enhance. The investment project is included in strategic documents such as Drought Effects Counteracting Plans and Flood Risk Management Plans. The authorities of Bierawa and Kuźnia Raciborska communes, State Forests and Kopalnia Piasku Kotlarnia S.A. will also participate in the implementation of the investment project. The planned area of the reservoir is approx. 900 ha. The capacity is approx. 40 million m³, of which the flood control capacity amounts to 24 million m³. The estimated cost of construction is approx. PLN 130 million, according to preliminary assumptions (the conclusive value of the investment project will be established on the basis of technical documentation after its preparation). The construction is scheduled for 2022–2027.

The next step to be taken by the signatories of the letter, in particular by the Communes of Kuźnia Raciborska, Bierawa and the investor – State Water Holding Polish Waters, will be financial engineering and securing funds.

Press Office State Water Holding Polish Waters

THE ŻELAZNA POLDER WILL BE **TWICE AS BIG**

The redevelopment of the Żelazna polder will double its area and the extension of the Odra flood embankment at the Kędzierzyn-Koźle municipal sewage treatment plant will reduce the risk of losses caused by high water. Flood protection for Opole and the surrounding towns will be improved.

The Żelazna polder is part of the Opole hydraylic system and one of the key facilities protecting residential and investment areas in Opole and the neighbouring communes. Built before 1939, it is currently undergoing reconstruction and expansion. The modernisation will be completed in 2023, and the polder area will increase from 200 ha to 400 ha. It will protect the area from the special economic zone in Opole, through inhabited areas on Partyzantów Street, the Sławice district, to the northern bypass of Opole. The towns of Żelazna, Dąbrowa and Dobrzeń Wielki will also be protected. The area include properties with an estimated value of PLN 800 million.

The cost of the ongoing 1st stage of the extension is approximately PLN 90 million. It covers earthworks, including the construction and reconstruction of flood embankments and accompanying facilities. Next, the Żelazna pumping station will be rebuilt, and the polder will ultimately retain 9.7 million m³ of water.

The embankment is currently being constructed and extended over a length of approximately 11 km. Preparatory works, roads and storage yards have been completed, and the low-voltage line colliding with the embankment has been reconstructed. At the same time, works on mobile pumping stations, which will operate in several parts of the polder, was commenced. The steel bulkheads are in place, necessary excavations were performed and the ground has been prepared for concreting the bottom slabs. Selected road and embankment culverts and the lower embankment of the Żelazna polder are being rebuilt. The equalising reservoir has already been dismantled and key elements of the polder are being constructed. The ground has been prepared for the construction of a new reservoir to replace the old one. The foundation for a new reservoir structure to replace the old one has been prepared. The bottom of the discharge structure has been desludged, reprofiled and the discharge flume channel was cleaned. The fittings of the present pumping station (six pump sets) were dismantled, concrete reprofiling of the walls of all intake chambers and the walls of all inlets to these chambers was carried out. All walls (without ceilings) in the pump hall were also reprofiled. Insulation of the pumping station building was completed. State Water Holding Polish Waters - Regional Water Management Board in Gliwice informs that the works on digging a ditch connecting the Ryjec riverbed with the Półwieś canal are almost complete. The reservoir is to provide protection against the effects of floods occurring once every 33 years.

Wojciech Kwinta
inzynieria.com

MODERNIZATION IN **THE PGE EO PSPP**

Modernisation of the metering and billing system (SPoRE) in pumped storage plants owned by PGE Energia Odnawialna has been completed. Thanks to the replacement of outdated equipment and IT systems, the company will be able to plan and settle the volume of production in power plants in Żarnowiec, Porąbka-Żar, Solina and Dychów with greater accuracy. The aim of the modernisation was also to adapt the system to the requirements of the energy market and the introduction of the capacity market.

The main task of SPoRE, apart from metering data collection, is to provide information on the status of generating units, production conditions or low performance of individual hydrogenerators. On their basis, reports, settlements and plans are drawn up. Modernisation of the SPoRe system was necessary as much of the installed equipment was outdated. The metering systems were more than twenty years old, and some meters were mounted on boards dating back to the 1960s.

Within the scope of works lasting seven months, in the pumped storage plants of PGE Energia Odnawialna, servers, operator stations, routers, network switches and meters were replaced. Moreover, the IT network, computer hardware and system, tool and analytical software responsible for the collection, processing, sharing and presentation of metering data were modernised. – Thanks to these changes, using the hourly data from the meters, we will be able to plan the production volumes in Żarnowiec, Porąbka-Żar, Solina and Dychów with great accuracy. This is all the more important as pumped storage plants have been, since this year, actively participating in the capacity market. Thus, by modernising the SPoRE system, we minimised the risk of a serious loss of revenues related to the lack of possibility to settle the system services - says Marcin Karlikowski, President of the Management Board of PGE Energia Odnawialna.

Press office
PGE EO

OVERHAUL OF **MYCZKOWCE SHP**

Almost sixty years after the commissioning of Myczkowce Dam, SHP Myczkowce has undergone a major overhaul. The retrofitting of the Kaplan-equipped hydroset shall ensure higher availability of the powerplant. The plant that has been set up to use environmental flow waters will be able to effectively utilise the potential energy of this flow to generate electricity.

Myczkowce SHP situated at the foot of the Myczkowce Dam located on the San river is a part of Hydropower Plant Complex Solina-Myczkowce.

STRATEGIC HP COMPLEX SOLINA--MYCZKOWCE

The key role in the HPP complex is occupied by the pumped storage Solina plant with 200 MW of installed power generation capacity, which is one of the largest pumped storage plants in Poland. Myczkowce HP serves an auxiliary function to the one performed by the Solina plant and it utilises flow that has been released by the pumped storage Solina plant and it serves a flow-compensating function, having an installed capacity of 8.32 MW. Lastly, the smallest of these objects, SHP Myczkowce is located by the dam and is using biological flow of the San river to operate. SHP operates continuously. On average, it produces about 1.3 GWh of electricity annually via 200 kW of installed capacity (source: www.pgeeo.pl). The entire infrastructure of the Hydropower Plant Complex Solina-Myczkowce is crucial in ensuring a stable operation of Poland's electric grid, as well as improving energy and flood security of the entire country and the region where it is situated.

AN UNUSUAL MAJOR OVERHAUL OF THE SHP

SHP Myczkowce is equipped with one hydroset that utilises a four-bladed Kaplan turbine to generate energy. The hydroset is working on 15 meters head and its maximum flow rate is 1.8 m³/s. The turbine is connected to an asynchronous generator via an elastic coupling. As a part of the overhaul there has been an appraisal and a repair of the entire hydraulic profiling of the turbine (including: its intake, guide vanes, turbine's cover, runner, runner's chamber, and turbine's suction pipe). Moreover, among other things – all the sealings and bearings have been replaced, together with the shaft connecting the runner to the generator. Faro Quantum ScanArm 3D scanning device has been utilised during the appraisal and repair of the profiling.

The important part of the overhaul project was to upgrade SHP's control and automation systems. The functionality of the current system has been improved owing to the replacement of the main control unit and implementation of a new SCADA system. Also, there has been an update to visualisation master system at pumped storage Solina plant, to accommodate the changes made at Myczkowce SHP. Myczkowce SHP has been adapted for safe, reliable and efficient operation.

All the repairs and improvements that have been implemented during the overhaul not only have allowed for secure operation and higher availability of the plant, but also have raised its energy generation parameters. Over several weeks of measurement after the SHP's handover, there has been an indication of increase in generated power of approximately 5% when compared with the situation before the overhaul. Such a change shall be tangibly translated into an increase in the amount of electricity produced. This means higher income for the owner, as well as environmental benefits. The example of SHP Myczkowce shows that every such an overhaul of a hydropower object has to be approached in a complex manner, allowing to identify any chances that may improve the efficiency of a plant. In this case, the definition of an overhaul took on a new meaning - because it has not only restored the original utility of the plant, but increased it as well - all while expanding the object's functionality and increasing its technological and economic efficiency.

Fig. 1. Outside view of the guiding vanes and the turbine's runner.

Fig. 2. Outside view of the water turbine.

IOZE HYDRO
TURN WATER ~ INTO PROFITS

IOZE Hydro, due to its notable experience in managing complex hydropower investment projects, was the general contractor for the overhaul works at Myczkowce SHP. IOZE hydro is experienced in the field of developing design documentation for overhauls, retrofitting and construction of SHPs, as well as conducting a turnkey construction of the new objects – including delivering its own turbines or performing the complex overhauls of existing hydrosets for its clients – both in Poland and abroad.

IOZE hydro

Łukasz Kalina
Development Department
IOZE hydro

Photos come from the archive of **IOZE hydro**

NEWS FROM **TRMEW**

With the end of the holidays, we saw the completion of the work on extending the support period from 15 to 17 for SHPs that have been benefiting from the FIT/FIP green certificate schemes for at least 5 years.

We have been working hard to include in the draft of the Act on Renewable Energy Sources the provision to extend the period of support under the FIT/FIP schemes by two years and all indications are that the target has been achieved. At the time of writing this note, we know that the draft has been submitted to the President for signature. Once the act comes into force, and this will most likely be in October, generators for whom the support period has already expired will be able to submit the relevant applications to obtain the "outstanding" support and benefit from the additional period. However, they must not miss this opportunity, as the deadlines for submitting the relevant applications are non-negotiable. For several weeks now, we have been actively working on further provisions for the modernisation of power plants after the end of the validity of support schemes and on the continuation of support schemes for systems whose high operating costs make it impossible for them to survive on the basis of market prices for energy. The work is difficult and time-consuming, but we stay positive and believe that our ideas will be introduced in the next amendment to the Act. In June, we organised a free webinar for our members and provided information on how to practically prepare for the extension of the support period. The form of organising such a virtual training was well received and we are considering organising such "meetings" more often. A week after the webinar, another "Uprawnienia Energetyczne D i E" training session took place, this time in Częstochowa. We are glad that another group of power plant owners and employees received certificates and became familiarised with information on how to maintain safety in their workplace.

There is one more cause for celebration – a few days ago Kongres Energetyka Wodna (Hydropower Congress) took place, which had to be cancelled last year due to a pandemic. During the event, there was plenty of information on how to approach the topic of modernisation, how to overcome problems resulting from the long deadlines for issuing water permits, and how the energy market will develop in the coming years and how to take advantage of it. Of course, we also talked about industry news and, what is most important at the moment, what to do to benefit from the additional 2 years of support under the FIT/FIP scheme. During this year's edition, our speakers included: Anna Łukaszewska-Trzeciakowska – Director of RZGW (Regional Water Management Board) in Warsaw, Jacek Jasnowski from the Ministry of Infrastructure, energy market expert Daniel Raczkiewicz. There was also a presentation prepared by a representative of URE – Mariusz Popiołek, as well as our irreplaceable representatives of TRMEW Management Board and partner companies. During the event, a lot of practical and substantial knowledge was provided and we are convinced that our guests, who came in large numbers, were satisfied. On the last day of the conference, we went on an excursion. We visited the Piaski sluice, Masurian Canal sluice and Mamerki. It was great to meet, talk and have a good time. We had not seen each other for a long time and we all really missed it! Thank you very much and see you at the next TRMEW conference!

Monika Grzybek
TRMEW office manager

CALENDAR

9–10.11.2021 Belgrade, Serbia	**4th Annual International Summit and Exhibition Balkans Power** *Organizer – Vostock Capital*	www.hydropowerbalkans.com
15.11.2021 Online	**Electricity Economics in Changing Electricity Markets** *Organizer – Infocus International*	www.infocusinternational.com
25–26.11.2021 Salzburg, Austria	**Hydropower trade fair & congress RENEXPO INTERHYDRO** *Organizer – Messezentrum Salzburg GmbH*	www.renexpo-interhydro.eu
23–24.02.2022 Kielce, Poland	**24th International Power Industry Fair and 19th Fair of Renewable Sources of Energy ENEX** *Organizer – Targi Kielce S.A.*	www.targikielce.pl
25–27.04.2022 Strasbourg, France	**HYDRO 2022 – International Conference and Exhibition** *Organizer – Aqua~Media International Ltd*	www.hydropower-dams.com

FROM **THE WORLD**

16.06.2021

ALL UNITS COMMISSIONED **AT WUDONGDE, CHINA**

All twelve 850 MW power units at the Wudongde hydropower plant were commissioned on 16 June, China Three Gorges Corporation has announced. The first units at the 10.2 GW plant began operating successfully on 29 June 2020, and with the final units commissioned the project has been completed on schedule. Wudongde hydropower plant ranks seventh in the world and fourth in China in terms of installed capacity. It is a multipurpose project providing flood protection, inland navigation and promoting local social and economic development in addition to generating clean power.

International Water Power & Dam Construction

25.06.2021

FIRST GW HYDRAULIC GENERATOR BEGINS POWER GENERATION TRIAL **AT BAIHETAN, CHINA**

China Three Gorges Corporation (CTG) has announced that the No.14 power unit on the right bank of its Baihetan hydropower station was successfully connected to the power grid on June 21, becoming the world's first GW-level hydraulic generator to undergo a power generation trial as the project races towards its official operation. Baihetan hydropower station is a supporting project for the implementation of the West-to-East Power Transmission Initiative as well as the construction of a clean, low-carbon, safe and efficient energy system in China. All of its units are scheduled to be put into operation in July 2022. Once in full operation, the station will be the world's second largest hydropower station after the Three Gorges dam, with an annual output of 62.443 billion kWh.

International Water Power & Dam Construction

2.08.2021

FUNDS APPROVED FOR NEW HYDRO **IN CÔTE D'IVOIRE**

The Emerging Africa Infrastructure Fund (EAIF), a Private Infrastructure Development Group (PIDG) company, has agreed to lend €25 million to Ivoire Hydro Energy (IHE) to help build a 44 MW hydroelectric plant on the Bandama River near the village of Singrobo in Côte d'Ivoire.

Expected to take three years to build, the Singrobo plant – the country's first hydroelectric development by an independent power producer – will cost an estimated €174 million to develop, and financial close is expected in late Q3 2021. The new plant will be an important strategic economic asset for Côte d'Ivoire. In addition to adding to the country's generation capacity, the plant enhances the system's flexibility, meaning it may be called in to meet baseload demand as well as peak demand.

International Water Power & Dam Construction

16.08.2021

NEW SMALL HYDRO SCHEME OPERATIONAL **IN ENGLAND**

A new 46 kW run-of-river hydroelectric scheme in Reading, Berkshire, England is now officially operational, with the plant set to generate 320 MWh for the local community. Located at Caversham Weir on the River Thames, the project features twin-screw Archimedes turbines and has been developed by Reading Hydro, a community benefit society set up especially the build the project. The scheme has cost £1.15 million and has mostly been financed by investment raised through community share offers. It will earn income by selling electricity and from the feed-in-tariff (FIT).

International Water Power & Dam Construction

17.08.2021

EN+ GROUP INSTALLS NEW IMPELLER **AT BRATSK**

En+ Group has begun installing a new impeller at one of its hydraulic units at the Bratsk Hydropower Station as part of its New Energy programme. Bratsk has 18 hydro-turbine impellers which have been undergoing a three-stage modernisation programme. In the first stage, which run from 2004 to 2010, hydraulic units 13–18 were rebuilt. Replacing the impellers at these turbines has improved the turbines' energy conversion efficiency to 95.3%. From 2014 to 2017, six further impellers were replaced on hydraulic units 6–10 and 12. All twelve impellers installed during the first two phases of the modernisation programme have already demonstrated their capacity for boosting efficiency and their modernisation has led to increased electric power production without an increase in water consumption. The remaining six impellers will be replaced during the final third stage of modernisation, which began in 2021. All necessary equipment has already arrived at the plant and is ready for installation. Works on the impellers are expected to continue till the end of the year, and the hydroturbine is planned for launch in late December 2021.

International Water Power & Dam Construction

LOAN AGREED FOR DAM **SAFETY PROJECT IN INDIA**

18.08.2021

The Government of India, the Central Water Commission, government representatives from 10 participating states and the World Bank have signed a $250 million project to support the Government of India's long-term dam safety program and improve the safety and performance of existing dams across various states of India.

The Second Dam Rehabilitation and Improvement Project (DRIP-2) will strengthen dam safety by building dam safety guidelines, bring in global experience, and introduce innovative technologies. Another major innovation envisaged under the project, that is likely to transform dam safety management in the country, is the introduction of a risk-based approach to dam asset management that will help to effectively allocate financial resources towards priority dam safety needs. The project will be implemented in approximately 120 dams across the states of Chhattisgarh, Gujarat, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Odisha, Rajasthan, and Tamil Nadu, and at the national level through the Central Water Commission (CWC). Other states or agencies may be added to the project during project implementation. "This is the world's largest dam management program. Its objective is to break the costly cycle of 'build-neglect-rebuild' which characterizes the operations and maintenance of infrastructure across sectors," said Junaid Ahmad, World Bank Country Director in India. "The expected outcomes will be game-changing: sustaining the livelihoods and food security of millions of Indians who depend on irrigated agriculture and enabling farmers to shift out of pumping groundwater, thereby, reducing energy consumption and greenhouse gas emissions."

International Water Power & Dam Construction

NEW REPORT SAYS HYDROPOWER NEEDED TO LIMIT **GLOBAL WARMING WILL FALL SHORT BY 300GW**

10.09.2021

A new report by researchers from the International Hydropower Association (IHA) has found there will be an over 300 GW shortfall in the amount of hydropower needed to limit dangerous global warming. The report – Hydropower 2050: Identifying the next 850+ GW towards 2050 – assesses pathways to net zero modelled by the IEA and International Renewable Energy Agency (IRENA), against current and future planned hydropower capacity.

Both IEA and IRENA models assess that in order to keep global warming to below 2°C, around 850 GW of new hydropower capacity will be required by 2050. More than 500 GW of hydropower installations are in the pipeline worldwide, but this leaves a gape of more than 300 GW says the report. For the more ambitious net zero target to limit temperature rise to below 1.5°C, more than 1.200 GW of additional hydropower capacity will be needed – leaving a gap of over 600 GW. Among the more than 500 GW in the pipeline, just 156 GW of this is under construction, with another 165 GW approved by regulators. The rest has been announced or is pending approval.

This remains significantly below the contribution required from hydropower under the IEA and IRENA models to reach net zero emissions. In 2020, annual growth in installed capacity was just 1.6 per cent – lower than the minimum 2 per cent growth required.

International Water Power & Dam Construction

URGENT ACTION NEEDED ON PUMPED STORAGE **SAYS INTERNATIONAL COALITION**

16.09.2021

More frequent blackouts and reverting to the use of fossil fuels could be on the cards unless urgent action is taken to scale up pumped storage, warns a government-led coalition.

The warning comes from the International Forum on Pumped Storage Hydropower, which has set forth seven major recommendations to avert the risk of policy-makers and grid operators falling back on fossil fuels to provide clean energy storage. It warns that, unless governments are willing to retain power plants fired by fossil fuels, they will need to invest in the clean energy storage provided by pumped storage hydropower. "Without adequate storage there is a very real risk that electricity grids of the future will not be able to provide reliable power without recourse to high carbon sources of back-up such as gas turbines," the report says.

The seven major policy recommendations which governments are urged to follow are:

- Assess long-term storage needs now, so that the most efficient options, which may take longer to build, are not lost.
- Ensure consistent, technology neutral comparisons between energy storage and flexibility options.
- Remunerate providers of essential electricity grid, storage, and flexibility services.
- Licensing and permitting should take advantage of internationally recognised sustainability tools.
- Ensure long-term revenue visibility with risk sharing to deliver the lowest overall cost to society.
- Assess and map for pumped storage hydropower among potential existing hydropower assets and prospective sites.
- Support and incentivise pumped storage hydropower in green recovery programmes and green finance mechanisms.

International Water Power & Dam Construction

HYDROPOWER EUROPE – A ROADMAP FOR EUROPEAN HYDROPOWER SECTOR DEVELOPMENT

The HYDROPOWER-EUROPE project is built on the ambition to achieve a research and innovation agenda and a technology roadmap for the hydropower sector, based on the synthesis of technical fora and transparent public debates through a forum that gathers all relevant stakeholders of the hydropower sector.

The ambitious plan for energy transition in Europe seeks to achieve a low-carbon climate-resilient future in a safe and cost-effective way serving as a worldwide example. The key role of electricity will be strongly reinforced in this energy transition. In many European countries, the phase out of nuclear and coal generation has started with a transition to new renewable sources comprising mainly solar and wind for electricity generation. However, solar and wind are variable energy sources and difficult to align with demand. Hydropower already supports integration of wind and solar energy into the supply grid through flexibility in generation as well as its potential for storage capacity. These services will be in much greater demand in order to achieve the energy transition in Europe, and worldwide. Hydropower has all the characteristics to serve as an excellent catalyst for a successful energy transition.

THE HYDROPOWER EUROPE FORUM

The Hydropower Europe forum gathers all stakeholders of the value chain of hydropower in Europe. It was launched by a Coordination and Support Action (CSA) funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 826010 over a period of three years from 2018 to 2021. Based on a wide European consultation, it has provided two main deliverables:

- the Research and Innovation Agenda (RIA),
- the Strategic Industry Roadmap (SIR).

Both deiverables can be downloaded from https://hydropower-europe.eu/. RIA provides technical recommendations for hydropower and SIR provides non technical recommendations to overcome barriers for targeting a European energy system with high flexibility and renewable share. The RIA aims to inform EU institutions and national authorities for research and innovation in the hydropower sector, the SIR aims to inform policymaking and the entire hydropower community of pathways to tackle economic, social and environmental challenges.

THE CONSULTATION PROCESS

Of the three-year programme, the first year was devoted to refining the methodology and organization of the first consultation events. In 2019, the participants of three regional workshops (Northern, Alps and Southern parts of Europe) analysed strengths, weaknesses opportunities and threats for hydropower. These analyses, combined with outputs from the first online Wider Stakeholder Consultation event (WSC), underpinned the first drafts of both deliverables. These drafts were then strengthened by undertaking a global system analysis of hydropower in Europe to better understand the key factors involved and to refine the drafts. The 2nd WSC, that took place in 2020, and the subsequent (online) Consultation Expert Panel (CEP) consultation events in February 2021 allowed for prioritisation of the R&I needs and of strategic actions required for hydropower to advance as the potential backbone of the European Green Deal.

THE RESEARCH AND INNOVATION AGENDA

The identified research themes are grouped according to seven challenges, which hydropower must address in Europe. In total 18 research themes, including several research topics for each of them, have been formulated from the 2nd WSC. After several workshops with the CEP the priorities, the suggested time horizon when the call should be initiated as well as the recommended funding scheme for all research themes could be defined as summarized in the Table below. For the more detailed research topics listed under each research theme also TRL was defined.

THE STRATEGIC INDUSTRY ROADMAP

Through its substantial programme of consultation, the HYDROPOWER EUROPE Forum defined the key strategic directions needed to support the role and development of hydropower. The present SIR outlines three deployment strategies for hydropower to overcome non-technical barriers to projects.

MARKET, POLITICAL AND LEGAL PATHWAYS TO THE 2050 NET ZERO ENERGY SYSTEM

There is a large consensus concerning the necessity to re-design the electric market. A new energy system, where renewable energies sources will only be used, needs a new market model. Fundamentally, storage and flexibility are externalities of Variable Renewable Energy supplies (VREs). Externalities are not addressed by the market; they are only controlled by regulation. The lack of compensation for many 'flexibility services' is called: "the missing money problem". Consequently, public regulation is crucial to properly remunerate storage and flexibility services. To implement a Zero Net Economy, investors need a more stable regulation framework. Policy measures that recognize the value of storage in the European power system, like abolishment of any kind of double taxation, will provide future revenues for flexibility and storage projects and can reduce investment risks and help ensure the economic viability of the European Green Deal.

An economic model giving a value to flexibility in the European power system is needed. Such a comprehensive modelling exercise, simulating a 100% renewable resources-based European energy system, would build quantitative evidence to support policymaking in pricing flexibility. All services provided to the grid should be fully compensated according to their value. A well-functioning single European energy market and an effective EU Emissions Trading System, which promote green renewable energy with a fair price, tax policy and a subsidy model designed to provide a level playing field amongst different technologies, based on a comprehensive analysis of their carbon footprint and life cycle, are the best way of ensuring fulfillment of the European energy policy objectives. Multi-criteria analyses should be considered in the tenders, giving value to indicators of energy consumption, carbon footprint and costs of the production, exploitation, recycling, and decommissioning. European policy could bring back a long-term vision and set long-term revenue streams securing future long-term investments.

SUSTAINABILITY IS THE SOCIAL PATHWAY TO THE EUROPEAN GREEN DEAL

Communication and dissemination are needed to increase the public awareness regarding the benefits and further support of new sustainable hydropower plants. Actions towards increasing social acceptance of hydropower are to make information more readily available, to develop specific strategies to quantify the benefits of hydropower and to share these messages with society. Regional workshops, gathering all stakeholders, under an appropriate administrative framework, are good opportunities to explore specific barriers and to promote best practice and uptake of hydropower. Large hydropower development may only occur if it is included within a coherent national energy policy, ensuring public water and energy services and security. In addition, robust sustainability standards and enforcement measures by national authorities are needed to increase investor confidence and gain public acceptance. The hydropower sector needs to adopt a holistic position considering the new social context, climate change, grid requirements and more generally the use of water for increasing social welfare. Development of comprehensive, innovative approaches, methods and tools using social sciences and humanities (SSH) are needed to help balance the European energy market rules and European environmental goals. Large reservoirs provide so important electric system security services such as prevention of network crashes, black-start, and regulation capabilities, that decision-makers and regulators must quickly protect and secure the independence and flexible operation of the European Electric System by launching new pumped-storage power plant solutions in Europe. Long-term support for hydropower 'know-how' is required to maintain and enhance hydropower in the future and to support continued employment in the sector.

THE ENVIRONMENTAL COMMITMENT IN THE EUROPEAN GREEN DEAL

A key collaborative action between hydropower stakeholders is to collect, share, disseminate and apply knowledge on best practice for protecting freshwater ecosystems. Collecting best practice with the help of international associations, best examples of biotope creation and restoration and lessons learnt from experiences with the water framework directive, drawbacks and limitations will help prevent, minimize, or support compensating for environmental impacts at the European level and support the discussion of approaches with up-to-date information. Increased monitoring and processing big data will help develop and share enhanced knowledge on ecosystems and how hydropower affects and mitigate these whilst supporting the Green Deal. A scientific program investigating, monitoring and benchmarking the application

Table 1. Recommended research themes, priorities, recommended funding schemes and time horizons for call (Legend of priorities: M = medium, H = high, V = very).

Recommendations from stakeholders		Priority				Budget (million €)				Time		
Research direction	**Actions**	**MH–H**	**H**	**H–VH**	**VH**	**2–7**	**8–15**	**16–25**	**26–35**	**<2025**	**<2030**	**<2035**
A **Increasing Flexibility**	**A1** Innovation in flexibility, storage design and operations				■				■	■		
	A2 Development and application of a business model for flexibility				■				■	■		
	A3 Innovative design of turbines including reversible pump-turbines and generators		■					■			■	
	A4 New models and simulation tools for harsher operation conditions		■				■				■	
B **Optimisation of operation and maintenance**	**B1** Monitoring systems for predictive maintenance and optimised maintenance intervals			■			■				■	
	B2 Digitalisation and Artificial Intelligence to advance instrumentation and controls		■					■			■	
C **Resilience of electromechanical equipment**	**C1** New materials for increased resistance and increased efficiency of equipment	■					■				■	
D **Resilience of infrastructures and operation**	**D1** Innovative sediment management technologies for sustainable reservoir capacity and river morphology restoration			■			■				■	
	D2 Databases of incidents and extreme events, integrated structural risk-analysis models and innovative solutions for multi-hazard risk analysis		■				■				■	
	D3 Innovative techniques for enhancement of overtopping safety of embankment and rockfill structures		■			■						■
	D4 New materials and structures for increased performance and resilience of infrastructures	■					■				■	
	D5 Innovative techniques for enhancement of useful life of concrete structures	■					■				■	
E **Developing new emerging concepts**	**E1** Development of innovative storage and pumped-storage power plants				■			■			■	
	E2 Hybrid & Virtual Power Plants			■			■				■	
	E3 Marine energy	■					■				■	
F **Environmental-compatible solutions**	**F1** Flow regime management, assessment of environmental flow release, innovative connectivity solution for fish and biodiversity protection and improvement of stored water quality in reservoir				■			■		■		
	F2 Assessment of general impact and contribution of hydropower to biodiversity and identification of innovative approaches and guidelines to support more sustainable hydropower development				■		■			■		
G **Mitigation of the impact of global warming**	**G1** Innovative concepts of hydropower infrastructure adaptation and tapping hidden hydro				■			■			■	

Source: Hydropower Europe

of best practice for protecting biodiversity and addressing climate change impact to improve knowledge and minimize impacts of industry and climate change on aquatic ecosystems is needed. Improvement of biodiversity protection and river continuity in hydropower projects thanks to innovative design and compensation measures is a key strategic action showing the environmental commitment of the hydropower sector. The development of innovative and comprehensive approaches to address environmental issues and biodiversity protection undertaking a synthesis of lessons that can be drawn from best practice and the latest research outputs and allowing sound and transparent discussion between all parties is a top priority.

THE SUSTAINABILITY OF THE HYDROPOWER EUROPE FORUM

Stakeholders from the whole hydropower value chain are represented within the Hydropower Europe Forum and its sustainability is important for promoting hydropower as an important player in the European Green deal. The collective knowledge of the stakeholders of the Hydropower Europe Forum is precious and essential for developing the role of hydropower as a catalyst for the energy transition and for disseminating key messages of both SIR and RIA efficiently and effectively.

Dr. Jean-Jacques Fry
President
European Club of ICOLD

The Hydropower Europe Forum, supported by a project funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 826010, has been preparing a Research and Innovation Agenda (RIA) and a Strategic Industry Roadmap (SIR) roadmap for the hydropower sector.

THE TECHNOLOGY OF VINYL SHEET PILES WITH GASKETS **IN THE CONSTRUCTION OF CUT-OFF WALLS**

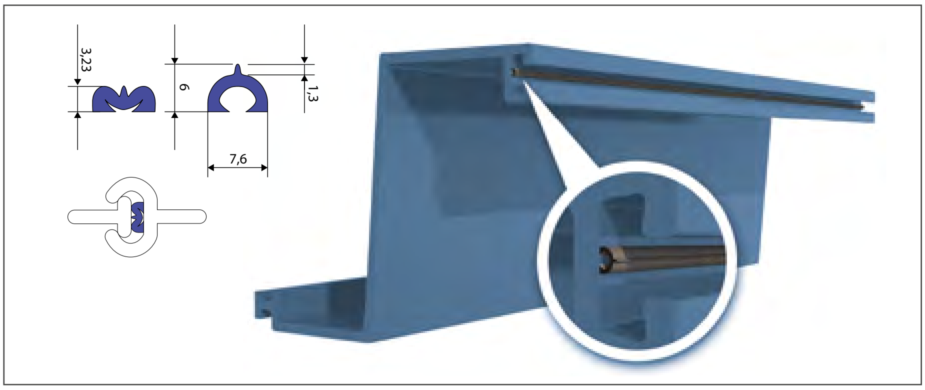
Anti-filtration barriers are important elements of hydrotechnical structures or waste landfills. Their primary objective is to significantly reduce or even completely prevent the migration of water or pollutants through the structure. The technology of vinyl sheet piles with gaskets seems to be a break – through alternative to traditional methods of building leak-proof cut-off walls in the ground.

Vinyl sheet piles have been known for over 30 years with the product first introduced to the US market in the 1980s. The technology has been gaining more and more supporters, especially in projects related to sealing and strengthening flood embankments. Growing prices of steel and conventional materials have recently contributed to an even greater interest in vinyl sheet piles, which have also been manufactured in Europe by the Pietrucha Group since 2006. The distinctive feature of the sheet piles from Poland is an innovative solution consisting in improving the existing manufacturing technologies by integrating the vinyl sheet profiles with a soft PVC gasket. Thanks to this innovative addition, the scope of projects where vinyl sheet piles may be applied extended to include anti-filtration barriers in the ground. What is worth highlighting, contrary to other technologies using, for example, steel sheet piles or CDMM / TrenchMix cut-off walls, the use of vinyl sheet piles results in instant tightness immediately upon installation, without the need to wait for the soil clogging effect to occur in locks or for hardening of the cement-ground mixture.

„Our goal was primarily to reduce the clearance compensation in the locks of vinyl sheet piles, but not at the cost of reducing their dimensions, which could increase the risk of damaging the lock when installing the sheet pile in the ground. Instead, we focused on adding a specialized gasket that, under pressure, will adjust to the clearance in the lock, tightly closing the filtration path of water or pollutants" Jacek Gralewski Head of R&D at the Pietrucha Group.

The gasket is not glued or stuck onto the lock in any way, but is thermally combined during the co-extrusion of the profile. As a result, it becomes a completely integral part of the entire sheet pile and there is no threat of damaging the gasket during the installation of sheet piles in the ground.

Fig. EcoLock sheet piles with an integrated gasket made of soft PVC type C.



FIELD TESTS AND FURTHER RESEARCH

Before being commercially introduced into production, the technology of vinyl sheet piles with a seal has undergone a series of tests in both laboratory and field conditions. Laboratory tests carried out by the Institute of Fluid-Flow Machinery at the Lodz University of Technology showed that the tightness parameter ρs of locks equipped with a gasket is 0, as evidenced by a certificate confirming the results of the tests performed. It was confirmed that the maximum pressure at which the tightness of such a solution was found was 2.0 bar, i.e. 20 meters of water column.

The field study consisted of the installation of a 12-meter long anti-filtration barrier made of vinyl sheet piles with a gasket installed in dense sandy soil with ID = 0.7. The length of the sheet piles used in this study was 10 meters. After correct assembly, the wall was excavated on both sides, to a depth of 5 meters, and a visual assessment of locks and sheet piles was made, which confirmed the 100% quality of the connection of female and male locks and the absence of cracks and damage. Then, one of the trenches was flooded with water in the amount of about 10,000 liters. The water was mixed with a red dye to better control leaks. The water level on one side was 2.5 meters. The test result also turned out to be positive, no leaks to the other side of the barrier were noticed at any point, neither in the bottom of the trench nor on the locks of vinyl sheet piles. The tests confirmed 100% tightness and operation of the gasket.

Fig. Tightness test of vinyl sheet piling with gaskets.

FAR FROM IDEAL WAYS TO SEAL CONVENTIONAL SOLUTIONS

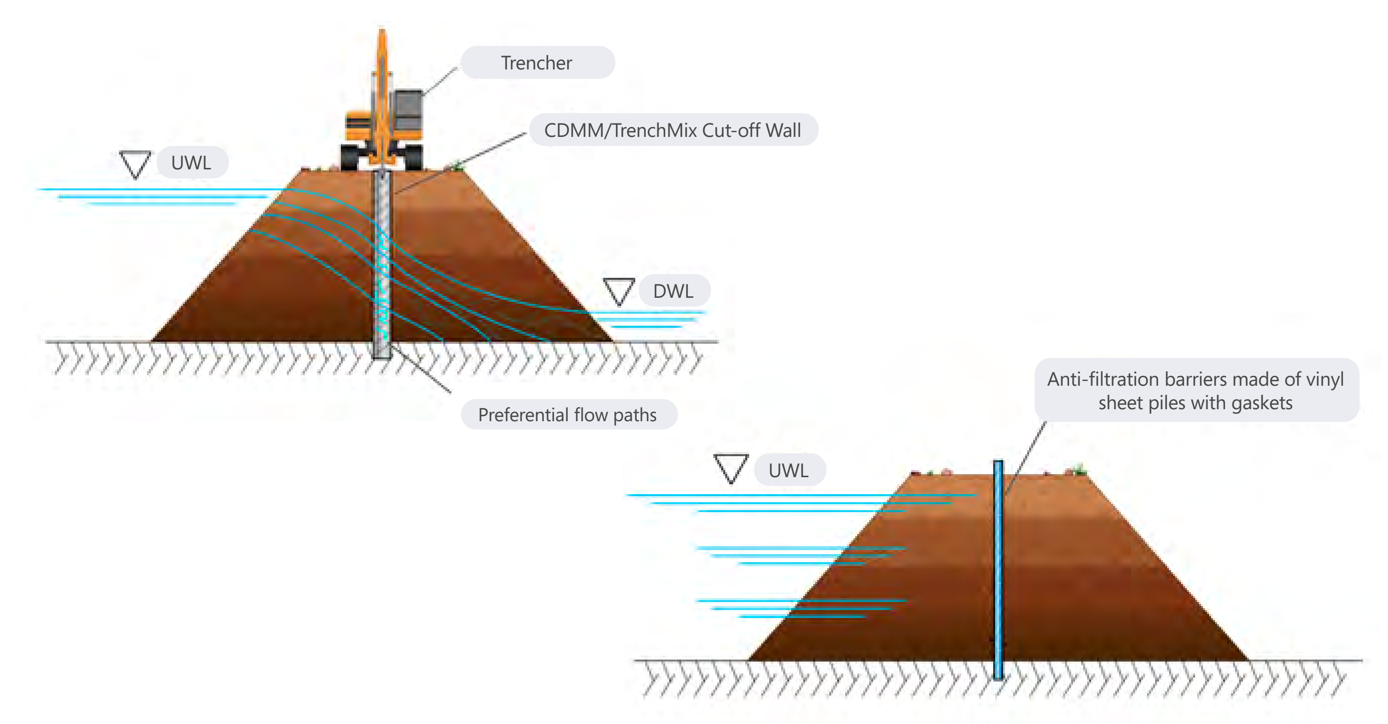
Steel

Standard steel sheet piles cannot integrate the gasket into the production process. The only known methods of sealing their joints are operations involving the application of bituminous masses and similar substances to the locks of sheet piles just before assembly. Such procedures extend the execution work time and increase its cost. In addition, when assembling at low temperatures, there is a problem with the rapid coagulation of these substances.

CDMM / TrenchMix

CDMM / TrenchMix cut-off walls are characterized by a low filtration coefficient, pro-

Fig. Embankments of a dam reservoir and potential risk of damaging the CDMM barrier vs. the embankment protected with cut-off wall made of vinyl sheet piles with gasket.



vided that they are properly made, taking into account both the soil and water conditions in a given place and selecting the appropriate cement-ground mixture. The disadvantage of such barriers is that it is difficult to objectively assess the quality of the cut-off wall in this technology. A major limitation in the applicability of this method is its use in reservoirs that keep water constantly, which are characterized by a large difference in water levels on the opposite sides of the barrier. The cement-ground barrier requires sufficient time to set. During this time, the accumulated water in the reservoir can gouge privileged filtration paths in the freshly made barrier. As a result, despite the concentration of the mixture, the barrier will not fulfill its task. With time, such a structure may again be exposed to the dangerous phenomena of suffosion and loss of stability. One cannot ignore the fact that the equipment used to make barriers in this technology has large dimensions and weight. Not all structures are adapted to be driven on them by such large vehicles.

VINYL SHEET PILING WITH GASKETS – COMPLETED PROJECTS

Kazakhstan

Vinyl sheet piles with gaskets were used in a complex project to build a sealed anti-filtration barrier around a tailings dam at an open-pit mine in Kazakhstan. The project was a challenge in many aspects. First of all, the size of the reservoir, which was 2 km wide and 2 km long required in total the construction of a 9 kilometre anti-filtration barrier. The installation works were carried out in extremely difficult soil conditions and adverse weather. There were 5–10 metre thick layers of very stiff sandy silt and dense silty sands, which in this dry climate turned into hard shell over time. Due to such difficult conditions, the attempted installation of 7mm thick steel sheet piling turned out to be a failure. The biggest challenge, however, was the requirement for the barrier to be 100% tight, because tailings stored in the reservoir was a lethal threat to the local population, in the event of contamination of underground freshwater intakes. The mine tailings, apart from heavy metals, may also contain acids and lyes, which are used in the process of ore extraction. As required by the client, the contracting company carried out periodic tightness checks of the barrier, in accordance with the standards methodology by the manufacturer during the field tests. Each time the test results were positive and the project was successfully completed. The construction of the cut-off wall lasted 12 months with breaks due to winter conditions.

Poland

Another project involving the use of vinyl sheet piles with a seal was the construction of an anti-filtration barrier protruding 0.5 m above the ground around the petrol station area in Central Poland. The necessity to build the cut-off wall was due to the fact that the area was exposed to water run-off during heavy rainfall and the surface waters contaminated with gasoline, diesel fuel and other dangerous substances, permeated the adjacent fields polluting the land intended for crops.

POTENTIAL USE IN HYDROTECHNICAL PROJECTS

The technology of vinyl sheet piles with an integrated gasket is used primarily in projects where extremely high tightness is required. In hydrotechnical engineering, the filtration coefficient of anti-filtration barriers should not exceeded $k=1*10^{-8}$. Such tightness cannot always be achieved using conventional methods. Using vinyl sheet piles with a gasket, with correct assembly, this factor is easily achieved. When constructing strategic flood embankments or dam reservoirs, both steel sheet piles and CDMM / TrenchMix cut-off walls may not achieve the required tightness due to the large difference in water pressure and the possibility of preferential flow paths. Vinyl sheet piles with a seal minimize water filtration through the anti-filtration barriers.

M. Sc. Eng. Dawid Jasiński

Translation: Justyna Kobos

Photos and graphics come from the archive **SiA Pietrucha Sp. z o.o.**

REINFORCING AND SEALING OF THE BOTTOM AND SLOPES OF HYDRO-ENGINEERING STRUCTURES **IN UNDERWATER CONDITIONS**

Derivative canals have been built and exploited for a long time, in Poland we can find such canals built even in the 1920s and 30s., so often their reinforcements are already 100 or more years old. Typical canal linings are reinforced concrete slabs, usually 20 cm thick, poured "dry" during construction.

Over time concrete cladding gradually degrades. Demaged and - leaky concrete of old canals causes an increase in the roughness of their beds and significant water losses, which leads to a decrease in canal capacity and a decrease in the efficiency of the powerplant. In addition, on sections running along the embankment there is a risk of stability and danger of landslides as a result of water leakage through them. The best, but also the most expensive way of renovating such an old canal is to remove the old concrete slabs and replace them with new ones made with the "dry" method, i.e. after emptying the canal (Fig. 1).

Unfortunately, due to local conditions and high costs, this method cannot be used often. Other methods are therefore needed to reinforce and to seal up canal bed and slopes with a new "wet" made cover, i.e. underwater, and preferably with minimal restriction of the current canal operation. Ideally, these methods should produce an effect as close as possible to concrete slabs made "dry", and therefore:

- reduce the active section of the canalas little as possible after the repair (minimum thickness of reinforcement);
- will be characterised by a relatively high smoothness so as to cause the least possible losses due to the roughness of the bed and slopes.

In order to compare how important these two issues are, a comparison calculation has been carried out below, applied to the two methods of canal renovation – "wet": 20 cm thick concrete overlay and 0.50 m thick: bentonite mat topped with gabions.

The bed: "old canal" before renovation:

- bottom width: 10.0 m
- depth of water in the canal: 5.0 m
- slope inclination: 1:1.5
- cover: old concrete with roughness coefficient:

Fig. 1. Concreting of new slabs in the dry canal of the Dychowski Canal, 2017, [10].

$$K_{St} = 60\frac{m^{-1/3}}{s}$$

- slope of the water table in the canal: I = 0.0005

Old canal bed lined with bentonite mate and loaded with 50 cm thick gabions

- roughness coefficient:

$$K_{St} = 45\frac{m^{-1/3}}{s}$$

Old canal bed lined with 20 cm thick Incomat® Standard concrete mattress, installed with "the wet"method

- roughness coefficient:

$$K_{St} = 55\frac{m^{-1/3}}{s}$$

The results of these calculations are summarised in Table 1.

According to the calculation results the flow in the canal protected with the gabion cover could decrease by as much as 37% compared to the situation before the renovation. The use of a layer of concrete in the Incomat® mattress reduces the overflow by only a dozen percents, so the height of any water back-up will be relatively small.

UNDERWATER CONCRETING UNDER CONTROLLED CONDITIONS

It is extremely difficult to make a concrete overlay of a specified thickness in under water conditions, at depths of several to a dozen metres and with practically zero visibility , and in the case of slopes it is downright impossible. In addition, when several – hundreds of running metres of a canal have to be repaired, the costs of such concrete cover would be very high. The solution is a specialised technology of a synthetic flexible formwork Incomat®. It is a mat consisting of two fabrics connected by spacers (bundles of threads of the appropriate length and strength placed at the appropriate spacing) that provide the desired target thickness of the concrete and shape of external surfaces. The concrete is pumped into the mat in liquid consistency, which allows for precise filling of the space between the upper and lower fabrics, and the spacers limit spread, creating in the end an uniform slab, also on

Table 1. Results of hydraulic calculations for a hypothetical derivative canal.

Type of reinforcement	Active section (m^2)	Speed of water flow (m/s)	Water flow (m^3/s)	Flow loss (%)
"Old Canal"	87.5	2.87	250.8	–
"Old canal" + gabions 50 cm	73.5	2.15	157.9	37.0
"Old canal" + concrete. 20 cm	83.3	2.63	218.8	12.7

Source: Own study

slopes. Mattresses sewn as "hollow quilts" are filled with concrete "in situ". The technology was developed and has been used since the 1970s. However, the idea itself was not then completely new, as Johann Store already proposed in 1922 the structure of breakwaters made from concrete blocks poured in a woven formwork, [1]. However, the precursor of synthetic mattresses is considered to be a Dutch engineer H.F. Hillen, who in 1965 used mattresses sewn similarly to traditional pillows [1]. This idea quickly found imitators and rationalisers [3], so that nowadays mattresses filled with concrete are increasingly used in hydraulic engineering in Europe, Asia, America and Africa, [4,5,6,7,8].

This solution is used in particular where the bottom and banks of canals have to be reinforced or sealed in underwater conditions. The mat can be used as a flexible formwork because it adheres well to the substrate during concrete filling due to the high elasticity of both fabrics, which is particularly important for underwater works. The upper fabric above the water surface is essentially a lost element, as it gradually degrades under prolonged UV-radiation. Thus, the upper surface will ultimately be bare concrete with a matted surface. The lower fabric, on the other hand, is a long-lasting element covered and permanently bonded to the concrete. In mats with spacers the lower fabric is additionally anchored in the concrete above it. Once the concrete has hardened and set, slabs are formed to protect the bottom and slopes from erosion and are integrated with lower fabrics and spacers. This is why reinforcements made using this technique can safely withstand high hydro-dynamic loads even with relatively small concrete thicknesses:

- wave height of 1.0–1.5 m depending on boundary conditions, [2]
- river or canal flow velocity up to 7 m/s, [2]
- height of water overflowing an embankment crown up to 1.0 m, [2].

RANGE OF SYNTHETIC MATTRESSES

There are 4 types of Incomat® mattresses: Standard, Flex, Crib and FP. Data on the parameters of the fabrics used for production are included in Table 2, and their shapes are shown in Figures 2, 3, 4, and 5.

Incomat® Standard is a mattress in the form of two woven fabrics with spacers connecting them together, when filled with concrete, a continuous concrete slab with guaranteed thickness and strength is formed, which is practically impermeable to water. The appropriate thickness of the mat and its shape are given by spacers, which can be selected in lengths from 8 to 56 cm. Hence, depending on the needs of the project, it is possible to obtain concrete thicknesses in the mat from 10 to 60 cm. This type of mat is most often used to seal the bottom and slopes of canals, in sections running along embankments. Data on the parameters of the fabrics used to manufacture Incomat® are included in Table 2.

Incomat® Flex, provides a pillow– like mattress with a varied form when filled with concrete. Filter points are sewn into the corners of the "pillows" so that the mat can be permeable to water.

"Pillows" take the form of a square with dimensions ranging from 80 x 80 cm to 120 x 120 cm. The mattress has spacers connecting the lower and upper fabrics to each other, which give them a form when filled with concrete. However, it is recommended that the geotextile is laid under the mattress each time, as the filter points could be damaged. In places where the mats are over extended, the concrete can be intentionally overloaded, which is why these mats

Table 2. Types of Incomat® synthetic mattresses.

INCOMAT® mattress types	**Crib® 10.100**	**Crib® 10.200**	**FP® C 60.148**	**Standard® 20.106**	**Standard® 20.108**	**Standard® 20.112**	**Standard® 20.116**	**Standard® 20.118**	**Standard® 20.130**
Material – mattress shell • longitudinal direction • lateral direction	PA PE	PA PE	PA PE	PA PE	PA PE	PA PE	PA PE	PA PE	PA PE
Tearing strength • longitudinal direction [kN/m] • lateral direction [kN/m]	45 25	45 25	55 50	45 25	45 25	45 25	45 25	45 25	45 25
Elongation after rupture • longitudinal direction [%] • lateral direction [%]	20 20	20 20	22 25	20 20	20 20	20 20	20 20	20 20	20 20
Water permeability [l/(m² x sec)]	20	20	20	20	20	20	20	20	20
Pore size "$O_{90\%}$" [μm]	330	330	330	330	330	330	330	330	330
Weight [g/m²]	410	410	400	400	400	400	400	400	400
Maximum thickness after filling [cm]	10	20	10	8	11	15	18	20	32

Source: Own study

Fig. 2. Incomat® Standard (left) schematic sketch with cross-section, (right) view of mattress after concrete filling, *photo: Huesker.*

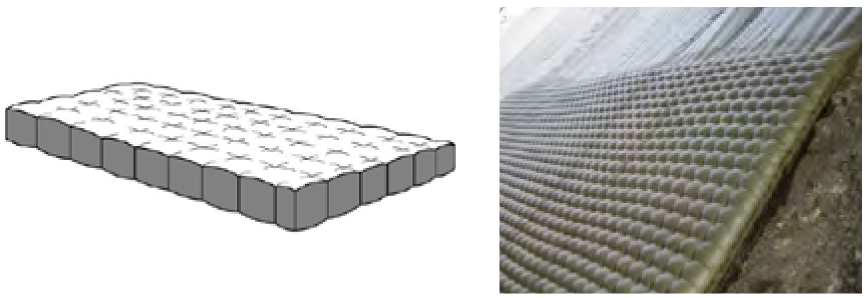
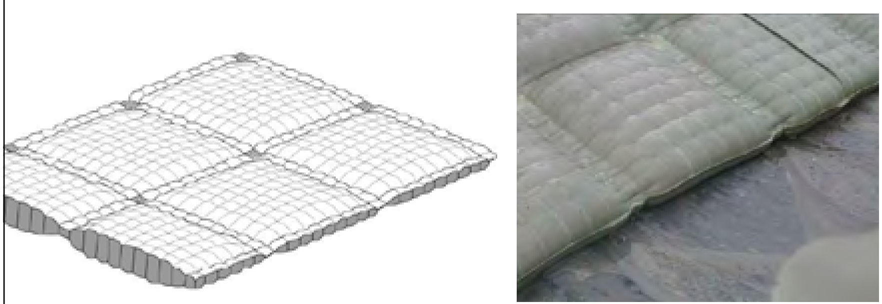
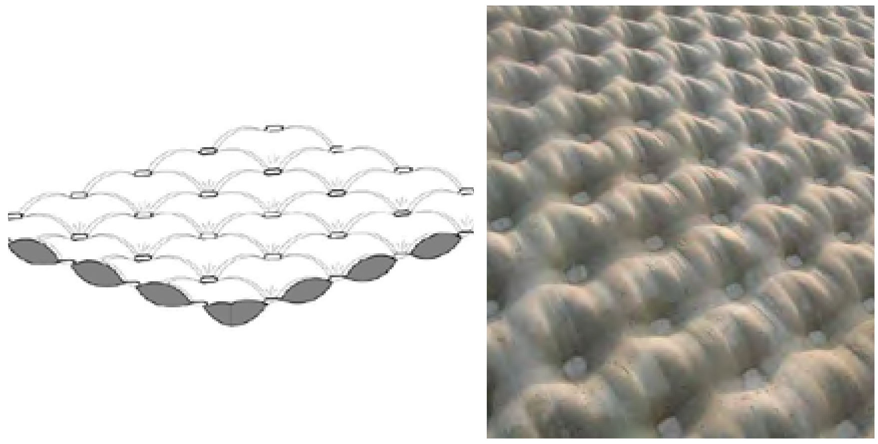


Fig. 3. Incomat® Flex (left) schematic sketch with cross section, (right) view of mattress after concrete filling, *photo: Huesker.*



are most often found in use on river banks with susceptible and uncertain substrate. The length of the spacers ranges from 8 to 56 cm, hence the average thickness of the mat can be from 10 to 45 cm. On canals, these mats are used on the excavated sections, i.e. when there may be groundwater inflow into the canal.

Fig. 5. Incomat® FP (left) schematic sketch with cross section, (right) view of mattress after concrete filling, *photo: Huesker.*



Incomat Crib®, a mattress in the form of ribs without spacers, where the "windows" between the ribs can be either fabric stitched together or open after the fabric has been cut out, averaging an alternate mattress thickness of 5 cm to 10 cm. Here too, the mat must always be lined with a geotextile fabric or non-woven to prevent the soil from being washed out from the "windows" This type is most often used as erosion control matting on river banks or dikes, or in the place of overflows on dikes.

Incomat® –FP, a mattress in the form of two fabrics with sewn-in filter points, the fabrics are sewn together using a special technique without spacers, the average substitute mat thickness is between 8 cm and 18 cm. It is a relatively light anti-erosion mat used above the water table to reinforce the bank for higher, short-time high water levels.

OVERVIEW OF APPLICATIONS

As already mentioned, Incomat® technology has been used worldwide since the 1970s. It is a specialised method that is often used when canals need to be sealed. Some of the larger realisations in Europe are, for example, the modernisations in France of the Canal de la Gentile (Fig. 6) and the Canal de Jonage (Fig. 8), or in Spain of the Canal Imperial de Aragon or the Mittlere-Isar-Kanal in Germany (Fig. 7). The synthetic mattress technology was used there successfully, protected the bottom and banks of the canals protected against the escape of water and the loss of stability of their dikes.

In most cases it is necessary to carry out wet rehabilitation works, i.e. the flow rate is temporarily reduced so that the water velocities are no more than 0.5 – 1.0 m/s. This is how the Mittlere-Isar-Kanal was repaired (Fig. 7). During the day, in the course of concrete and installation works, the canal worked only to compensate its own water losses, [9]. Each night, however, the canal was switched back to normal operation so that the loss of non-produced electricity was as low as possible. Here a special floating pontoon was used for installation of mattresses and pumping of concrete (Fig. 7). On both sides- of the bottom panel, slope panels were sewn and rolled out in the factory, the slope panels were rolled up from the bottom and then filled with concrete using the "bottom to top" technique. Up to 3 panels with a total surface area of around 3.000 m² were laid and filled with concrete per day using this technique. A slightly different technique was used during the renovation of the Canal de Jonage in France (Fig. 8), where 33 m x 36 m panels were used, stapled together at the factory and delivered to the site on special pallets. These relatively large panels were lowered and sunk from a pontoon, the positioning of the mat and its stable positioning being ensured by piles driven into the bottom of the Canal de Jonage, to which loops were applied, positioned at the edge of the panels. In this case, one bank of the canal was in an excavation and the other in a dike form, the dike was at risk, where its sealing had failed,. i.e. the bank was endangered by sliding.

An even different technique was used on two sections of the Dychow Canal in 2018 (Fig. 9). Here, panels measuring 30 m x 33.4 m were pulled from one bank to the other on ropes stretched over the canal (Fig. 9). The mat was then sunk using sandbags under the control of 2 to 3 divers. The underwater panels were connected to each other before concreting with the aid of sewn-in zippers. Concrete was pumped into the mat with the assistance of PE pipes (Fig. 10).

The concrete used was underwater, self-compacting SCC with modifying additives such as AWA and PP fibres added at a rate of 1 kg/m³, [10]. The required concrete class C30/37 was easily achieved:– strength tests carried out after 28 and 56 days gave the following results: 51.6 MPa and 60.5 MPa. The watertightness of class W8 was achieved and there were no objections to the consistency and stability of the concrete during concreting of the mattresses. After the concrete had hardened, the top of the mat was cut to the designed level with a circular saw, the final state after cutting the mat is shown on the Fig. 11.

Fig. 4. Incomat® Crib (left) schematic sketch with cross section, (right) view of mattress after concrete filling, *photo: Huesker.*

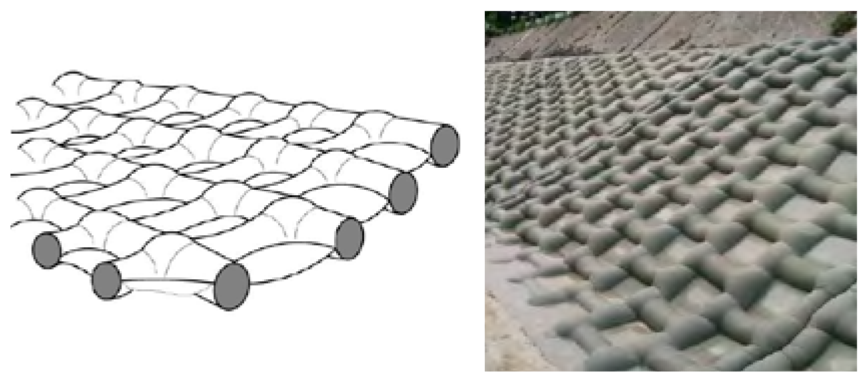


Fig. 6. Canal de la Gentile, (left) mats laid and top anchored, (right) sequential concrete filling, Incomat® Standard 1999–2000, *photo: Huesker.*

Fig. 7. Mittlere-Isar-Kanal, installation and concreting of the Incomat® Standard, bottom panel being lowered from the ramp, rolls of slope mats can be seen on both sides, *photo: Huesker.*

Fig. 8. Canal de Jonage, Installation of Incomat® Standard panel from a pontoon, together with the application of anchor loops to piles to stabilise the mats in flowing water conditions 1994, *photo: Huesker.*

Fig. 9. Dychowski Canal, dragging an Incomat® panel from one bank to the other on support cables, 2018, *photo: HZ-Bud.*

Fig. 10. Dychowski Canal, final phase of concrete pumping for part of the Incomat® Standard panel, 2018, *photo: Inora.*

Fig. 11. Dychowski Canal, the left photo shows the concrete filled mattress before final treatment and the right photo shows the concrete mattress after the top flange has been cut off by approximately 1.0 m, [10].

CONCLUDING REMARKS

The Incomat® system has proven itself on many hydro-engineering structures, also in Poland. According to the author, this is a better system than, for example, bentonite matting loaded down with gabions. First of all, the use of gabions significantly reduces the active cross-section of the canal and leads to a higher roughness of its bed and banks. Overtime gabions become overgrown with bushes and other vegetation and catch a considerable amount of floating matter including rubbish in the canal, which further increases the roughness of its banks.

Relatively thin concrete slab ca. 15 - 20 cm thick synthetic casing provides a continuous sealing shield and reinforces the canal bed and slopes, while slightly reducing the canal flow capacity. Another important advantage is that concrete works can be carried out underwater, even at moderate water velocities in the canal. Therefore, in the author's opinion, synthetic mattresses can be considered the best solution for sealing of old canals or dikes, dam repairs, protection against erosion of harbour basin bottoms or outports of locks and weirs.

EngD Janusz Sobolewski
P.R. INORA sp. z o.o.
Polish Geotechnical Committee Certificate No. 0201

Bibliography:

1. Pilarczyk K., Geosynthetics and geosystems in hydraulic and costal engineering, A. A. Balkema, Rotterdam, 2000
2. Pilarczyk K., Incomat, Conrete filled geotextile mattresses, 1998, typescript
3. Zitscher F., Kunststoffe für den Wasserbau, Verlag von Ernst & Sohn, Berlin, München, Düsseldorf, 1971
4. Straßler K.-H., Rehm H., Instantsetzung der Kraftwerkstreppe Mittlere Isar, Neue Abdichtun- gstechnologien, 15. Gemeinschafts-Symposium der Wasserbau-Institute, TU München, TU Graz, ETH Zürich, Wallgau Obernbayern, 2010, pp. 67–78
5. Noritzsch M., Rehm H., Sanierung eines Kraftwerkskanals beim Teilanstau mit Betonmatten, Wasser Wirtschaft 12/2010, pp. 22–26
6. Sobolewski J., Report from demonstration of concrete filling of Incomat® synthetic mattress on the slope and a sand filling geocontainer of SoilTain® at the base of the dike, Marine Engineering and Geotechnics, 2011, No. 5, pp. 428–435
7. Hawkswood M. G., Sobolewski J., Pilch M., Geosynthetic concrete mats in the protection of the bottom of quays and ship berths, Marine Engineering and Geotechnics, 2014, No. 3, pp. 229–238
8. Siah M.K., Rahimi H., Jafari A., Ghotbi Sh., Moulaie M.J., Rehabilitation of Irrigation Canals in Iran, ICID Journal, Vol. 46, No. 2, pp.61–80
9. Wilke M., Derksen J., Betonmatten und deren Anwendung als Deckwerkssystem, 48. IWASA, Mitteilungen d. Lehrstuhls f. Wasserbau u. Wasserwirtschaft, RWTH Aachen University, 1978-Band 172, pp. 48–58
10. Fiks K., Piechocki M., Kozakiewicz J., Poręba W., Application of SCC concrete technology on the example of modernization in EW Dychów, XVIII Conference on Concrete Rheology, Warsaw 2019, pp. 151–166

PROMOTING THE EUROPEAN SMALL **HYDROPOWER INDUSTRY**

The European small hydropower industry is considered to be a world leader, able to build tailor-made hydropower facilities all around the world. European hydropower equipment manufacturing competence accounted for an estimated two-thirds of the world market.

The Small Hydropower Chapter of the European Renewable Energies Federation (EREF) represents the small hydropower sector at EU level. EREF and its members aim to secure and enhance small hydropower's place as an equally important contributor to Europe's renewable energy mix and to create business opportunities for the many small and medium-sized independent hydropower producers. The Chapter hosts and moderates several networks of hydropower associations and industry stakeholders.

EU SMALL HYDROPOWER INDUSTRY INITIATIVE

EREF, in cooperation with partners from the EU project HYPOSO, initiated the EU Small Hydropower Industry Initiative which focusses on the involvement of and information about the European industry and its technological leadership. Part of this campaign is the HYPOSO Project which aims at supporting the European hydropower industry and stimulating the energy transition in developing and emerging countries. Thirteen project partners from Europe, Africa and Latin America work together to achieve an increase in the share of renewable energy through sustainable hydropower solutions as well as rural electrification in the target countries Bolivia, Cameroon, Colombia, Ecuador and Uganda. The project also seeks better investment conditions in the target countries by providing policy recommendation papers to decision-makers.

The HYPOSO project includes important tools for hydropower stakeholders such as a framework analyses with regard to small hydropower up to 10 MW for selected target countries (Bolivia, Cameroon, Colombia, Ecuador and Uganda) and the HYPOSO Map, which includes more than 2,000 potential hydropower sites in Bolivia, Cameroon, Colombia, Ecuador and Uganda. To promote this process, project partners, in cooperation with local experts and political stakeholders, prepare 15 dedicated business case studies of small hydropower projects with a focus on local financing, leading to at least 5 signed Memorandum of Understanding (MoU) between stakeholders from target countries and the European hydropower sector. Capacity building of local stakeholders (i.e. hydropower professionals – young and senior, political deciders) complements the activities mentioned above.

INSIGHT ON INNOVATIONS

With regard to the EU Small Hydropower Industry Initiative, the project provides two important tools for relevant stakeholders and decision-makers, the Handbook on European small hydropower technology and the HYPOSO Platform. These two tools serve as a basis for the promotion of European equipment producers, project developers and investors abroad. It should also help EU decision-makers to create better framework conditions for the domestic small hydropower sector.

After an image video about the EU hydropower industry, EREF and its partners have developed a new handbook on European small hydropower technologies and solutions. This promotional tool includes the latest innovation underlining the strength and international leadership of the European industry. This handbook is disseminated outside the EU onwards, and is available in English, French and Spanish to support the engagement and activities of European companies outside Europe.

JOIN SHP WORLDWIDE COMMUNITY

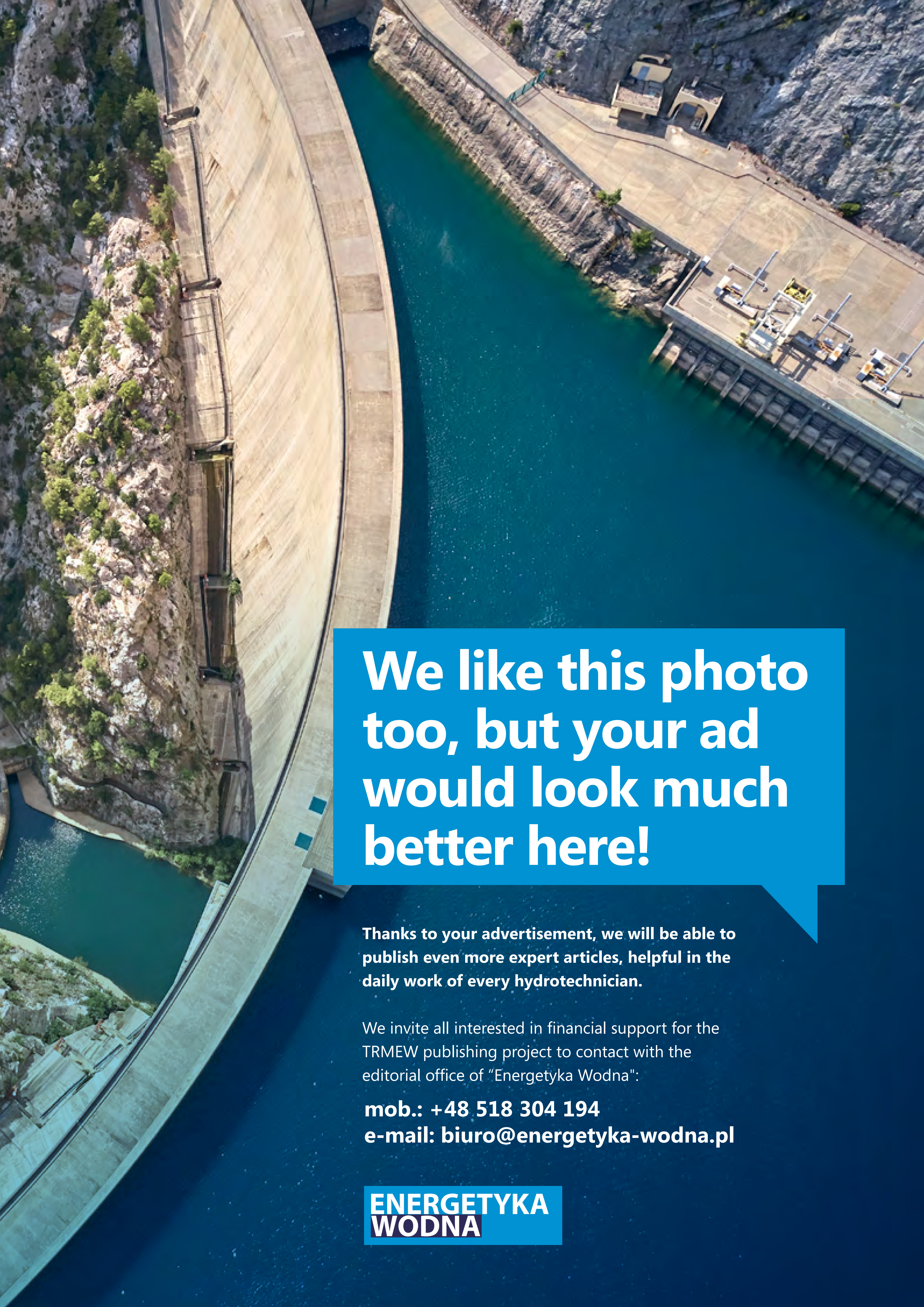
The HYPOSO Platform, an online meeting place for stakeholders from the EU as well as from the target countries brings together hydropower stakeholders from the European Union with their counterparts in the HYPOSO target countries. EREF and its members and partners have developed a first comprehensive dataset of, among others, the European small hydropower industry, which did not exist before. The HYPOSO platform offers the opportunity for the stakeholders of the European hydropower industry to give more insights on their activities including contact persons and contact details. The platform allows for the filtering by region and stakeholder type thus facilitating the search for interested parties to find potential business partners. It is open for interested companies, institutions and/or organisations and can be accessed via: www.hyposo.eu/en/hyposo-platform/.

Stakeholders are also invited to join the HYPOSO LinkedIn discussion group and/or follow the project at twitter. Both channels can be accessed via the website www.hyposo.eu/en/home/ which further informs about ongoing project activities.

If the pandemic permits, several events will be carried out in the target countries (with matchmaking events for EU and local stakeholders in Uganda and Colombia), as well as in Europe. The HYPOSO newsletter will inform in about the upcoming events (www.hyposo.eu/en/home/#newsletter).

The author would like to thank the European Commission and the Innovation and Networks Executive Agency (INEA) for the support of the HYPOSO project. The HYPOSO project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857851. The sole responsibility for the content of this paper lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the INEA nor the European Commission are responsible for any use that may be made of the information contained therein.

Dirk Hendricks
Secretary General
European Renewable Energies Federation (EREF)


We like this photo too, but your ad would look much better here!
Thanks to your advertisement, we will be able to publish even more expert articles, helpful in the daily work of every hydrotechnician.
We invite all interested in financial support for the TRMEW publishing project to contact with the editorial office of "Energetyka Wodna":
mob.: +48 518 304 194
e-mail: biuro@energetyka-wodna.pl
ENERGETYKA WODNA

HYDAC – YOUR PARTNER FOR CLOSED **HYDROPOWER COOLING SYSTEMS**

Hydropower plants make a decisive contribution to sustainable energy supply worldwide. HYDAC demonstrates its expertise in the hydropower industry with its extensive product portfolio. The comprehensive product range comprises hydraulic products, electronic control technology, magnetic network technology, control sensors as well as fluid sensors/condition, monitoring and fluid maintenance products.

HYDAC is regarded today as the perfect partner for all hydropower projects requiring fluid power in connection with hydraulics, electronics an engineering. HYDAC has decades of experience in oil hydraulics and process water treatment. With individual components constantly being added to the product range, such as filters, accumulators, valves, pumps, coolers and sensors. HYDAC has built up an extensive and complete product portfolio over the years that leaves nothing to be desired when it comes to designing systems for the hydropower industry. In addition to supplying individual components, HYDAC also provides complete systems for almost all hydropower applications. These are comprehensive systems which are specially tailored to suit the customer's needs.

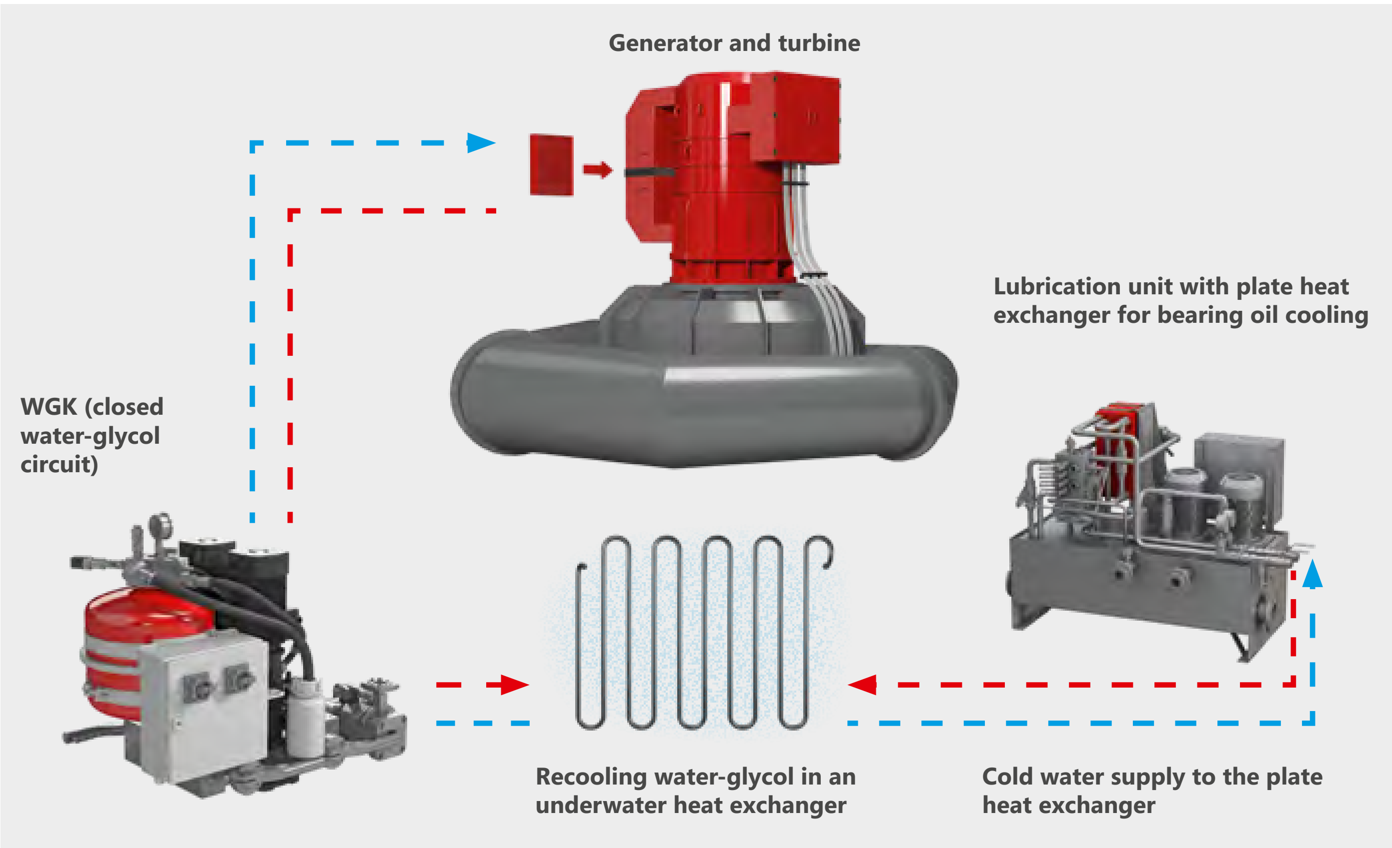
COOLING SYSTEMS IMPROVE EFFICIENCY

When energy is generated in hydropower plants, some loss in caused by the heating of copper windings and bearings. The task of the cooling systems in to dissipate the heat. They help to improve efficiency, prevent damage and excessive wear and thus reduce the life cycle costs. The HYDAC WGK is a compact and modular system for closed cooling circuits that work with cooling media such as water glycol and water and that are used above all to cool the generator and to cool hydraulic power units in conjunction with a submerged heat exchanger.

This main components of the WGK are one or more pump-motor units for flow rates of up to 1500 l/min, expansion tank and additional sensors, such as pressure switches, pressure sensors and pressure relief valve, venting valve and pressure gauge. The cooling fluids is normally recooled by means of heat exchangers positioned underwater. Air coolers or plate heat exchangers can also be connected, however, which also serve to

Fig. 1. For closed cooling circuits operating with water glycol, HYDAC has developed a compact system (WGK) consisting of a motor pump unit, an expansion tank a mixing valve and sensors.

Fig. 2. Cooling of the generator and bearing lubricating oil using an immersion exchanger.



heat the machine cabin or cool the hydraulic fluid. The modular system is specially designed for use in hydropower plants and contains precisely those components that are needed for his purpose.

CHARACTERISTICS OF COMPONENTS

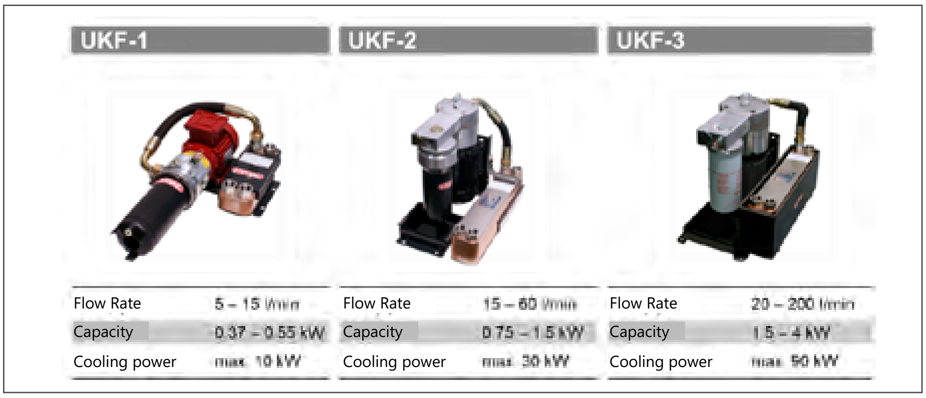
For increased availability and safety:

- Closed circuit to avoid fluid loss and fluid deterioration
- Redundant motor-pump group
- 3/2 – way mixing valve for consistent temperature of the coolant and to avoid condensation.

Amplified and predictive maintenance:

- Ball valves and butterfly valves for service during operation
- Maintenance-free magnetically coupled pump seal (mag-drive) instead of wear-prone shaft seal
- IO-Link sensors (optionally also with master)
- Resistance temperature sensor with evaluation electronics or additional temperature transmitters
- Pressure transmitters make it possible to determine the flow rate on the basis of Δp and pump characteristics.

Fig. 3. Hydac cooling system components.



WGK VIRTUALLY MAINTENANCE-FREE

One of the main features of closed cooling circuits is that they require practically zero maintenance once installed and they can also be positioned flexibly. This is why HYDAC WGKs have been used to cool generators and frequency converters in wind turbines for decades. This experience is incorporated into the continuous development and optimisation of the cooling circuits. The modularity of the WGKs makes it possible to configure the cooling circuit to suit its particular application and the desired flow rate. With its many years of experience in fluid engineering, HYDAC Technical Sales can support you and assist you in making the right selection.

The contact us via our website or by using for following e-mail-address: techniczny@hydac.com.pl

The HYDAC team looks forward to hearing from you!

HYDAC Sp. z o.o.

Photos and graphics come from the archive of **HYDAC Sp. z o.o.**

Source: Gerd Altmann, iStock

EUROPEAN GREEN DEAL **AND HYDROPOWER**

The European Green Deal is a new EU strategy for environmental and climate protection. In the coming years, it will significantly influence EU actions and lead to numerous changes in law. Hydropower sector is likely to be a beneficiary of the changes as a desirable renewable energy source. However, the potential risks, e.g. related to fish protection, cannot be ignored.

How can the European Green Deal affect EU law? From a formal point of view, the European Green Deal is a proposal by the European Commission on how to change EU law to increase the level of environmental and climate protection[1]. As the Commission points out, the European Green Deal is a new strategy for growth that aims to transform the EU into a just and prosperous society within a modern, resource-efficient and competitive economy that achieves zero net greenhouse gas emissions by 2050 and decouples economic growth from the use of natural resources[2]. Examples of potential actions bringing upon that vision are described in the Annex to the Communication (the "Annex").

To clarify, the European Green Deal is only a Communication, i.e. a general idea and not a binding law. EU law is adopted in various ways, depending on its form and content. In terms of form, EU derived law can be divided into legislative acts and hierarchically less important non-legislative acts, including implementing and delegated acts. The division of acts into regulations, directives and decisions relates to their type and in this context is less relevant[3]. EU environmental law is based on legislative acts. In the current legal state, they are adopted, as a rule, under the ordinary legislative procedure, i.e. both the European Parliament and the Council of the European Union must agree on their final content[4]. In exceptional situations, e.g. in the case of regulations of primarily fiscal nature, acts concerning environmental protection are adopted under a special legislative procedure, which boils down to the fact that the decisive vote is held by the Council, i.e. in practice by the EU Member States[5]. This means that the ideas contained in the European Green Deal may never enter into force, e.g. because they will not be accepted by the Council. Therefore, the remainder of the text refers not only to the European Green Deal, but also to other related EU activities, especially those that have already taken place after the Communication was adopted.

A PROPOSAL FOR ACTION UNDER THE EUROPEAN GREEN DEAL

The European Green Deal includes many different actions. The different initiatives are divided into nine groups, namely:

1) more ambitious EU climate targets for 2030 and 2050,
2) the provision of clean, affordable and secure energy,
3) a circular economy,
4) sustainable and intelligent mobility,
5) sustainable agriculture,
6) protection and restoration of ecosystems and biodiversity,

7) reduction of pollutant emissions,
8) mainstreaming sustainable development in all EU policies, and
9) the EU's role as a global leader in climate and environmental protection.

Firstly, the EU's ambitious climate goals are to reduce emissions of greenhouse gases, such as those from burning fossil fuels to generate electricity, in order to protect the climate from their concentrations and consequent climate change[6]. Some of the measures announced in the European Green Deal have already been implemented, e.g. the European Climate Law has been adopted, which assumes that the EU will achieve climate neutrality by 2050 and reduce emissions by 55% by 2030 compared to the levels in 1990[7]. Moreover, the so-called FIT 55, a package of legislative proposals amending specific pieces of EU climate protection legislation, such as the EU Emissions Trading Scheme (EU ETS)[8], was also presented. The second goal of the European Green Deal is to ensure clean, affordable and secure energy[9]. The EU's priority is energy efficiency, i.e. limiting energy consumption[10]. Energy production should be based on renewable sources, e.g. hydropower.

Another element of the European Green Deal is a circular economy, i.e. ensuring that raw materials are recycled and reused in the economy[11]. Hydropower does not generally produce waste, so the proposed changes will not directly affect it to any real extent. Similarly, the new EU industrial strategy does not refer to hydropower[12]. Another element of the Green New Deal is sustainable and intelligent mobility, which assumes, among other things, reducing emissions by replacing traditional fuels, such as petrol, with alternative fuels that do not generate emissions, such as electricity[13]. The EU also wants to support multimodal transport, including transport of goods by rivers. For this reason, the rules of combined transport will probably be changed[14]. Additionally, from 2021. The EU wants to increase initiatives to increase and better manage railway and inland waterway capacity[15].

Although the agricultural objectives are less relevant for hydropower sector, the role of European fishermen, in particular supported by the Common Agricultural Policy, should not be completely overlooked[16]. Planned changes to the Common Agricultural Policy consist of provisions protecting the water quality or increasing the potential of sustainable seafood as a source of food with a low carbon footprint. Ecosystems serve most basic needs, such as food, fresh water, clean air and shelter[17]. The EU Biodiversity Strategy 2030 has already been presented[18]. The Commission also stresses the role of a sustainable blue economy, i.e. using the oceans to mitigate and adapt to climate change[19]. According to the Commission, ensuring a non-toxic environment requires greater efforts to prevent new pollution, as well as action to reduce and remove existing pollution[20].

In general, the Union will also seek to mainstream sustainable development in all its policies in line with the general principle of "Do no harm to the environment". However, this is likely to require increased financial investment, particularly in the area of energy transition. For this purpose, among others, a new Fund for Just Transition has already been created, amounting to about 20 billion EUR[21]. We should also remember about the role of the so-called taxonomy, i.e. a new EU law which is to redirect private financial resources to possibly ecological investments[22]. Lastly, in the spirit of "geopolitical Commission" European Green Deal projects the EU as a global leader in transformation and climate diplomacy and trade. However, those aims are not crucial for the hydropower sector.

THE EUROPEAN GREEN DEAL AND HYDROPOWER

Essentially, hydropower can be defined in different ways. For example, in the Polish Law on Renewable Energy Sources "hydropower" is understood as the mechanical energy of water, excluding the energy obtained from pumping work in pumped storage or pumped hydroelectric power plants[23]. For the purpose of this article hydropower will be understood as a renewable energy source installation that produces electricity from the above mentioned hydropower. However, the article focuses on small power plants, such as those found in Poland, and not large installations which in practice do not exist in Poland and probably will not exist in the near future. It seems that the most important changes for hydropower may concern several issues, both in terms of opportunities and risks.

In particular, in terms of opportunities, the most important is the increased role of renewable energy sources at the expense of fossil fuel energy, which creates space for the development of new hydropower plants. Reforms are likely to lead to an increase in the price of electricity for consumers. The higher price of energy, with no increase in the cost of its production as a result of new regulations, is an opportunity for greater profitability of projects, and consequently favours their implementation. Additionally, different RES have different advantages and disadvantages. It can be assumed that photovoltaic and wind power plants will have the largest share in RES in Poland. However, the disadvantage of these technologies is their lack of controllability, i.e. to simplify, photovoltaic panels work only when the sun shines, so they do not generate energy at night. Hydropower plants are also not fully controllable, but because they continue to operate while other RES stop, e.g. wind turbines (due to low wind) or photovoltaics (due to night time), they can complement the above mentioned sources in the power system. In other words, the advantage of hydropower is that it is different from the most popular RES – it can continuously operate with less dependence on the weather circumstances.

Under the reform, RES are supposed to be more accessible to local communities and not, for example, only to international financial investors. When wind farms are relatively large and capital-intensive investments, hydropower can be developed on a local scale. Thus, it seems that this could be another opportunity for hydropower, if only the regulatory environment, particularly regarding ownership and profits from power plants, is suitably investor-friendly. Harnessing the potential of water power in electricity generation would contribute to fulfilling many of the goals set out in the European Green Deal. Currently, only a fraction of the hydropower potential is exploited.

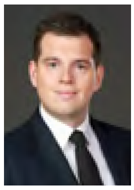
It's worth adding, that the EU has actively pursued solutions that will allow the use of hydropower resources even before the adoption of the European Green Deal. One such effort is the funding of the FIT hydro project[24]. The first stage of the project was to determine the impact of hydropower plants on the most relevant environmental aspects, i.e.: upstream and downstream migration of fish, water flow, habitats and sediments. This was followed by the development of measures that would allow for the sustainable use of water while providing adequate protection for ichthyofauna populations. As a result, scientists have identified more than 20 solutions, methods, tools and instruments that should facilitate the use of hydropower in a sustainable manner that protects fish populations. These include a unique system that helps fish safely navigate between hydropower turbines, a fish-tracking device based on 3D optical technology and ultrasonic modules, and a system for predicting risk associated with fish mortality. As part of the project, the researchers also developed a number of methods aimed at supporting decision-making about hydropower plants and raising public awareness about hydropower[25]. The project was conducted between November 2016 and April 2021, with financial support from the EU of EUR 5,888,423. It appears that the adoption of the European Green Deal may increase the real impact of EU efforts to promote hydropower.

However, the European Green Deal may also have a negative impact on hydropower, particularly if regulations for the protection of biodiversity, including ichthyofauna, are tightened. Fortunately, most measures are likely to be related to forest protection, including against deforestation, which is less relevant to the hydropower. The widespread use of water as a power source also faces other constraints, such as the risk of flooding.

CONCLUSIONS

All in all, the European Green Deal will dominate EU activities in the near future, and almost all citizens and businesses will be affected by the changes. The implementation of the provisions of the European Green Deal brings with it certain opportunities and risks for the hydropower area. Further development of hydropower is beneficial for the implementation of some of the provisions set out in the European Green Deal, however it may be with a harm to other provisions. Nevertheless, positive impacts of this development rather outweigh the potential losses. To a certain extent, wider use of hydropower will contribute to the goals of meeting climate goals, providing clean energy and the goals of sustainable development. Hydroelectricity has special considerations here, as it represents one of the cheapest and least carbon-intensive sources of available electricity. Thus, it will become one of the most competitive RES sources in terms of profitability.

On the other hand, the operation of hydropower plants carries risks to the ecosystems and the preservation of their biodiversity. Powering hydroelectric turbines entails damming up available water resources, which at the same time changes the local ecosystem and blocks the passage of fish. Therefore, there is a risk of tightening the regulations of biodiversity protection. However, the above risk should be treated as a certain eventuality and not put on a par with certainty. The European Union recognizes the potential of water power as a renewable and clean source of electricity. Therefore, it strives to establish measures that will allow the popularization of hydropower while limiting the negative effects that hydropower has on the protection of ecosystems and biodiversity.



Radosław Maruszkin PhD
lawyer

MARUSZKIN
PRAWO - ŚRODOWISKO - KLIMAT

[1] European Commission, Communication From The Commission To The European Parliament, The European Council, The Council, The European Economic And Social Committee And The Committee Of The Regions "The European Green Deal", COM/2019/640 final, further:"Communication"

[2] Communication, p.2

[3] European Union, Consolidated version of the Treaty on the Functioning of the European Union, 13 December 2007, 2008/C 115/01, p. 125, art. 288, further "TFEU"

[4] TFEU, art. 192 ss. 1

[5] TFEU art. 192 ss. 2

[6] Cf. M. Popkierwicz, A. Kardaś, Nauka o klimacie, Warsaw, 2018

[7] European Parliament, Council of the European Union, Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999, Official Journal of the European Union, L 243, 9 July 2021

[8] European Parliament, Council of the European Union, Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive) 96/61/EC (Text with EEA relevance, Official Journal of the European Union, L 275, 25 October 2003

[9] Communication, p. 6-8

[10] European Parliament, Council of the European Union, Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (Text with EEA relevance), Official Journal of the European Union, L 315, 14 November 2012

[11] Communication, p. 8-11

[12] European Commission, Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions Updating the 2020 New Industrial Strategy: Building a stronger Single Market for Europe's recovery COM/2021/350 final

[13] Communication, p. 13

[14] European Commission, Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions EU Biodiversity Strategy for 2030 Bringing nature back into our livesCOM/2020/380 final, Annex p.3, further as "Annex"

[15] Ibidem.

[16] Communication p. 14

[17] Communication p. 15

[18] Annex, p.4

[19] Communication, p 16

[20] Communication p. 17

[21] European Parliament, Council of the European Union, Regulation (EU) 2021/1056 of the European Parliament and of the Council of 24 June 2021 establishing the Just Transition Fund PE/5/2021/REV/1, Official Journal of the European Union, L 231, 30 June 2021, p. 1-20

[22] European Parliament, Council of the European Union, Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088 (Text with EEA relevance), Official Journal of the European Union, L 198, 22 June 2020, p. 13–43

[23] Ustawa z dnia 20 lutego 2015 r. o odnawialnych źródłach energii, Dz.U.2021.610 t.j. z dnia 2021.04.01, art. 2 ss. 12.

[24] Cf. https://www.fithydro.eu/introduction/

[25] Cf. https://ec.europa.eu/research-and-innovation/pl/projects/success-stories/all/zrownowazona-energia-wodna-staje-sie-rzeczywistoscia

INDUSTRY CATALOG

AQUA TECH
MOVABLE WATER DAMS

+48 530 133 269
+48 32 441 77 17
biuro@aqua-tech.info.pl
www.aqua-tech.info.pl
Lipcowa 64
32-540 Trzebinia

ENERKO energy
turn plans into reality

EPC Contracting of Hydropower Project

Łukasz Kalina
e-mail: **lukasz.kalina@enerko.pl**
phone: **+48 41 301 00 27**
mobile: **+48 512 008 805**
www.enerko.pl

OZE instytut
turn idea into solutions

Hydropower Engineer

Michał Kubecki
e-mail: **michal.kubecki@ioze.pl**
mobile: **+48 505 176 479**
ul. Skrajna 41a
25-650 Kielce
www.instytutoze.pl

COMPLEXED INSURANCE PROGRAMME DEDICATED FOR SMALL HYDROPOWER PLANTS

- All -risk property Insurance
- Compensation of profit loss by randomly occurred events
- Compensation provided in the event of profit loss caused by breakdown on recipient side
- Compensation of profit loss on mechanical devices demage under producer's warranty

KO-RO kancelaria brokerska
kancelaria@ko-ro.pl
ul. Grabiszyńska 200/71
53-333 Wrocław
www.ko-ro.pl
tel. 0 713640376

MAVEL
Hydro turbines

Mavel, a.s.
Jana Nohy 1237
CZ - 256 01 Benešov
sintak@mavel.com
+420 602 317 524
www.mavel.com

WODEL NOWA SÓL
WATER TURBINE MANUFACTURER

PBiEEW WODEL Sp.z o.o.
40, Piłsudskiego Street
67-100 Nowa Sól
Poland
Mobile: +48501302648, +48502608102
wodel@wodel.pl
www.wodel.pl

WTW
WTW POLAND Sp. z o.o.
www.wtw-poland.com

IS YOUR
AD MISSING?

Order an entry in the branch catalog for only 60 € net!

Energetyka Wodna
mob.: +48 518 304 194
e-mail: biuro@energetyka-wodna.pl

ADDITIONAL TWO YEARS OF SUPPORT **FOR SHP IS NOW A REALITY!**

The Polish Parliament completed the work on the government's draft act on amending the Act on Renewable Energy Sources and certain other acts. The Act, passed by the Sejm on 17 September 2021, has been sent to the President for signature and shall enter into force 14 days after its publication in the Journal of Laws. In the course of the parliamentary work, the draft Act followed a rather long and bumpy road, during which quite a few amendments were made.

In the previous issues of "Energetyka Wodna" (EW), we presented the regulations included in the draft Act at different stages of its processing. Now we know the final shape of the Act and this article will briefly present the regulations that will soon enter into force. The article will discuss several, important from the point of view of the hydropower industry, issues. Particular attention will be paid to the statutory solutions which crown the efforts of the Polish Association for Small Hydropower Development (TRMEW) to ensure that energy generators using SHPs have the right conditions to continue operating.

17 YEARS OF SUPPORT FOR SHPS UNDER FIT AND FIP SCHEMES

The most important of the results of the cooperation between the TRMEW and the relevant Ministry is the legislation that can be called a lifeline for hundreds of small hydropower plants (SHPs), especially for those for which the 15–year support period expired last October. The provision contained in the Act passed by the Sejm on 17 September this year extends from 15 to 17 years the period of support under the feed-in tariff (FIT) and feed-in premium (FIP) schemes for SHPs and biogas plants which benefited from green certificates for at least 5 years.

It should be remembered that both the installations which are still using the support system and those for which the previous 15–year period has already expired will benefit from the provisions of the Act. Eligible installations shall be able to benefit from the additional two years of support regardless of whether they have already "migrated" to the FIT/FIP scheme or whether they still benefit from the green certificate or auction schemes and will switch to FIT/FIP only after the new regulations enter into force. The extension of support has been implemented slightly differently for each of these groups and the course of support will be described in detail in the transitional provisions.

After the amendment to the Act comes into force, power plants benefiting from the FIT/FIP schemes that have already lost the support right will be able to apply for covering the so-called negative balance, i.e. the difference between the prices guaranteed by these systems and the market price of electricity for the period when they were not supported, and then "return" to monthly settlements under the FIT or FIP schemes. For those installations, the period for which they will receive payment of the negative balance and the period when they will be able to benefit from FIT/FIP again will not exceed a total of 17 years. The additional period of support will be 24 months from the end date indicated on the certificate issued by the Energy Regulatory Office (URE) on the eligibility for the FIT or FIP scheme.

On the other hand, power plants that applied for green certificates until the end of the 15–year support period and have not switched to the FIT/FIP schemes will have to undergo a "migration" procedure, i.e. join the FIT/FIP. For those plants, the 2–year period of additional support will count from the moment of obtaining a certificate from URE on the possibility of benefiting from FIT/FIP schemes. These installations will not receive payments for the "gap" period during which they did not receive support. Finally, for installations for which the support period has not yet ended and which currently operate under the FIT/FIP scheme or will "migrate" to it from the certificate or auction schemes and have been in the green certificate support scheme for at least 5 years, the support period will automatically apply for a total of 17 years.

IMPORTANT DATES AND PROCEDURES

For all the cases described above, there is a specific time limit for submitting the relevant applications and declarations. For example, the owners of installations that previously benefited from the FIT or FIT support scheme and for which the 15–year support period has already expired will have 60 days from the moment the Act enters into force to submit to Zarządca Rozliczeń S.A. the aforementioned application for payment of the negative balance for energy produced in the period from the date of expiry of the 15–year support period to the date of entry into force of the Act. Such applications shall be submitted by all generators – regardless of the size of the system, i.e. also by those who have not applied to Zarządca Rozliczeń S.A. for payment of the negative balance under the FIT scheme so far, in case this was done for them by the authorised dealer. If, after the one-time settlement of the "outstanding" amount of support, the generator benefiting from the FIT support scheme before the entry into force of the Act wishes to remain in the same scheme, it should conclude an agreement with the authorised dealer within a month. On the other hand, if, after the settlement of the "outstanding" payment by Zarządca Rozliczeń S.A., the generator previously covered by the FIT support scheme wishes to sell electricity to a chosen company on the market company and settle the negative balance (i.e. switch to further settlements under the FIP scheme), it should, within one month from the date of entry into force of the Act, amend the declaration submitted to URE when joining the scheme.

For generators benefiting from certificates of origin or support schemes, other procedures are provided. If the 15–year period of support for their power plants has already expired, they will be able to benefit from the extension of this period provided that they join the FIT/FIP scheme (i.e. submit a declaration of their intention to benefit from this support scheme to URE) within 90 days from the entry into force of the Act. In the previous issue, the EW readers could already read the description of deadlines and procedures related to the extension of support. This information is quoted here again to alert SHP owners to the fact that the deadlines introduced by the Act are non-negotiable. Generators who fail to take appropriate action within a specified time will not be able to take advantage of the opportunity offered by the regulation. It should be noted that the group of potential beneficiaries is large. In October 2020, nearly 400 SHPs lost their right to support and since then new hydropower plants built after 2005 regularly join this group.

DEFINITIONS

Apart from the provisions on which the SHP sector has recently focused the most, the Act passed by the Sejm on 11 August also included other important issues. Several of them are included in the glossary. Firstly, the definition of a small RES installation has changed. The upper threshold of the total installed capacity of facilities that will be allowed to be included in that group has been raised from 500 kW to 1 MW. Thus, a small installation will be a renewable energy source system with the total installed capacity of more than 50 kW and less than 1 MW, connected to an electrical grid with a rated voltage of less than 110 kV or with the cogenerated heat output of more than 150 kW and less than 3 MW, where the total installed capacity is more than 50 kW and less than 1 MW. The main effect of this change will be the limitation of licence obligations for entrepreneurs performing the economic activity in the field of energy production from RES, as generators owning small systems are exempt from the obligation to hold a licence. This will facilitate procedures for investors implementing new projects, and generators operating existing RES systems between 500 kW and 1 MW will be transferred ex officio to the register of energy generators operating small installations.

The second important issue is to clarify the method of determining the total installed capacity of a RES installations, in line with the current practice in this respect set out by the Energy Regulatory Office. Pursuant to the Act, the installed capacity of a RES plant shall mean the total nominal active power of a generator, a PV module or a fuel cell indicated by the manufacturer on the rating plate. Different definition applies only to biogas systems.

DURATION OF SUPPORT SCHEMES

Another vital area where changes were implemented is the extension of the maximum duration of the FIT, FIP and auction support schemes. The obligation to purchase energy under these mechanisms has been extended until 30 June 2047, and the possibility to join the schemes until 31 December 2027, although these proposals require the approval of the European Commission. On the other hand, prior to the Commission's approval, the Act allows the possibility to join the FIT/FIP schemes until 30 June 2024, and in the auction scheme until 31 December 2021. At this point, one may also mention the introduction of the basis for creating a six–year support schedule under the auction scheme. This is because the Act contains a delegation to issue, instead of regulations published each year, a single regulation specifying the quantities and values of energy that may be auctioned between 2022 and 2027.

OTHER CHANGES

Some introduced regulations relevant for renewable sources go beyond the scope of the Act on RES. For example, the amendment provides for changes in the area of spatial planning. In accordance with the currently binding regulations, RES installations with a capacity exceeding 100 kW shall be taken into account in the study of land use conditions and directions and in local spatial development plans. The regulation increases this threshold to 500 kW.

Changes of somewhat lesser importance include e.g. shortening the period of positive balance compensation to three years with a return period of up to 6 months from the end of a given period. The provisions concerning cooperatives have also been modified, among others, in such a way that for members of cooperatives the rules of functioning in the cooperative are comparable to operating in the prosumer system. A provision that clarifies that for the purposes of the Act, including the application of the preferences provided for energy cooperatives, a member of an energy cooperative may be an entity whose system is connected to the electrical grid, has been added. The solutions contained in the Act are not intended to change the rules for creating cooperatives, but only to clarify certain issues related to cooperatives.

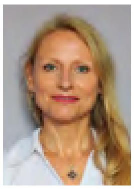
WHAT WAS MISSING IN THE ACT

The turbulent fate of the proposed legislation on hybrid sources was presented in issue 1/2021 of EW. Ultimately, neither the Act of 20 May 2021 amending the Act on Energy Law and some other acts (Dz. U. / Journal of Laws/ of 2021, item 1093), which was discussed then and already passed, nor the Act passed by the Sejm on 17 September, discussed in this article, introduced any new definitions and solutions concerning this type of systems.

The extension of support under the FIT and FIP schemes by 2 years is, as said at the introduction, a lifeline for the SHP industry, without which many hydropower plants would probably go out of business today. However, it is only a bridging solution that will sustain production in existing SHPs for a short period only. The next deadline for the end of the support period for 400 generators in SHP is 30 September 2022. Therefore, one might say that from the perspective of the hydropower industry, the Act lacks legal solutions that would ensure the operation of these sources in the long term. Such a solution would be the system of operating support for those RES technologies for which the period of basic support has expired and whose operating costs make it impossible to function on the basis of market, wholesale energy prices, as postulated by the industry.

The second solution consists of provisions regulating the possibility to carry out modernisation of RES installations, which would allow a RES system to be upgraded or completely renewed and to benefit from the support scheme again.

However, both mechanisms require not only their introduction into the legal system but also notification of the European Commission. Nonetheless, time passes and it may turn out that the period of operation of the bridging regulations will be insufficient for the target solutions to come into force, which will result in another "gap" during which energy generators using SHP will be forced to operate their facilities without economic justification.



Ewa Malicka
President of the Polish Association
for Small Hydropower Development (TRMEW)

CONTRACTORS' FINANCIAL CLAIMS RELATED **TO AN EXTENDED TIME OF PROJECT PERFORMANCE**

A delayed contract performance and a resultant extension of the construction projects duration causes a situation where contractors incur additional (not included in the agreed remuneration) indirect costs, and very often higher direct costs. This, in turn, may result in a loss of anticipated profits or even in a substantial (often many times higher than the contract value!) loss.

In the construction practice delays and time extension are a common phenomenon. When it happens, contractors must answer the question: whether they are entitled to pursue any claims, and if yes – which ones. To help to answer this question, below we briefly discuss the nature of certain claims.

ADDITIONAL INDIRECT COSTS

Indirect costs are one of the main components of the contractor's remuneration under a construction contract. Pursuant to § 1(2)(4) of the Regulation of the Infrastructure Minister of 18 May 2004[1], indirect costs constitute "a calculation component of the cost estimate value including costs that are not included in direct costs and constituting tax deductible costs under separate provisions, in particular construction overheads and management costs". They do not constitute direct costs of construction works performance. Indirect costs, in addition to direct costs, are the second main component of the construction projects costs, and they increase as the contract performance time extends.

Indirect costs include the contractor's overheads and management costs. The overheads are expenses necessary to ensure general construction production conditions, and to handle, organise, and administer the construction[2]. The ways of demonstrating that overheads expenses have been incurred depend on the type of a given cost. In the case of "external" expenses, such as costs of office lease, site security, works insurance, they may be demonstrated based on invoices issued by service providers/suppliers, and payment confirmations. Another group of overheads are "internal" expenses, e.g. costs of salaries for the managing staff that may be demonstrated on the basis of a payroll, confirmations of salary payment, or statements of the contractor's staff.

Management costs are a group of indirect costs associated with the handling, maintaining, administering, managing, and organising of the contractor understood as a whole enterprise. These costs are calculated on the basis of financial data of the contractor's enterprise based on the commonly used formulas, such as Eichley, Emden or Hudson formulas.

Generally, if the time of works performance gets extended for reasons attributable to the employer, the contractor's claim for a reimbursement for additional (not included in the remuneration) indirect costs arises on the first day of the project performance after the original completion date agreed in the contract. The value of this claim increases with each day of the extended contract duration. The contractor may consider pursuing claims for a reimbursement for additional indirect costs as damages or due to the employer's unjust enrichment[3]. In certain cases, if the time extension is caused by an unpredictable change in circumstances, it is also worth considering founding a claim on the rebus sic stantibus clause.

ADDITIONAL DIRECT COSTS

Direct costs are the main price component when it comes to a remuneration for construction works. Direct costs consist of costs of labour, materials, and operation of equipment necessary to perform one unit specified in the bill of quantities. Depending on the type of a direct cost, its amount is determined by various factors, for instance, labour costs depend on the statutory minimum salary, while costs of equipment operation depend on fuel prices. However, the greatest changes exceeding the standard contract risk concern prices of construction materials.

The amended Public Procurement Law that came into force on 1 January 2021 provides for an obligation to provide a valorisation clause for construction contracts concluded for a term longer than 12 months.

Expenses that the contractor incurs during the contract performance may result from a delay, if during the delay the prices/costs of works performance rise. A price increase and related additional expenses may also arise regardless of a delay. Depending on the circumstances regarding a given project, it is possible to assert claims covering additional direct costs against the employer. The claims value will often be calculated by comparing the costs incurred with the costs initially anticipated by the contractor at the bidding stage.

An analysis of potential claims should start with a verification whether the given contract contains a valorisation clause. More and more frequently contracts concluded in the public procurement regime contain valorisation clauses aimed to mitigate adverse consequences of an increase in costs of the contract performance. The amended Public Procurement Law that came into force on 1 January 2021 provides for an obligation to provide a valorisation clause for construction contracts concluded for a term longer than 12 months.

However, the practice shows that valorisation clauses contained in public contracts do not fully compensate the expenses associated with increased costs of the works performance. In this situation it is worth considering whether the contractor has other options to claim a reimbursement for additional costs. If a cost increase is deemed to be extraordinary and poses a risk of a substantial loss for the contractor, which could not be predicted by the parties when concluding the contract, a claim

[1] Regulation of the Infrastructure Minister of 18 May 2004 on methods and bases for preparing an investor cost estimate, calculating anticipated design works costs, and anticipated costs of construction works specified in a functional and utility programme ("Regulation")

[2] B. Kacprzyk, Kosztorysowanie obiektów i robót budowlanych, Polcen, Warsaw 2010.

[3] E.g. Judgment of the Appellate Court in Warsaw of 9 May 2018, I ACa 57/17.

for an increase of remuneration may be founded on the rebus sic stantibus clause (art. 3571[4] § 1 of the Civil Code).

Nonetheless, in practice an increase in costs of the works performance often is not extraordinary or refers only to a small specific group of materials. In such situation it should be analysed whether the additional direct costs incurred by the contractor due to an increase in materials prices can be linked to any circumstances attributable to the employer. If the contractor incurred additional costs due to works being delayed for some reasons attributable to the employer, this may constitute a ground for pursuing a claim for damages. In this situation it is necessary to demonstrate an adequate causal connection between the damage and the improper performance of the contract by the employer.

CLAIMS LIMIT AND LEGAL BASIS

A claim for damages due to incurring additional direct and indirect costs is limited to the value of the actual damage incurred by the contractor including a loss and lost profits. Accordingly, damage would mean incurring additional expenses that the contractor would have not incurred if the works had not been delayed for reasons attributable to the employer. In each case it is necessary to demonstrate an adequate causal connection between the damage and the employer's actions.

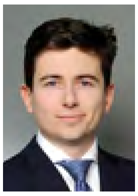
A claim arising from unjust enrichment includes a profit (savings) that the employer gained at the contractor's expense. It is worth mentioning that a restitution covers an equivalent of the contractor's actual impoverishment. A claim based on the rebus sic stantibus clause is limited to the value of a loss suffered or threatened. However, it should be stressed that a court deciding on a remuneration change will try to restore the contract balance and to distribute the loss between the investment process participants instead of fully compensating the contractor's loss.

Each increase in direct or indirect costs arising from the performance of works in an

> *A claim for damages due to incurring additional direct and indirect costs is limited to the value of the actual damage incurred by the contractor including a loss and lost profits*

extended time requires an analysis of the reasons for a delay. This allows to choose an optimal legal strategy, and to assess which claims are most likely to be successful and how to document the costs incurred.

Andrzej Sokołowski
Attorney-at-law
Partner in the Litigation and Arbitration Team, the Infrastructure Team
JDP Law Firm



Iwo Franaszczyk
Attorney-at-law
Associate in the Litigation and Arbitration Team, the Infrastructure Team
JDP Law Firm

[4] clause of extraordinary change of relations

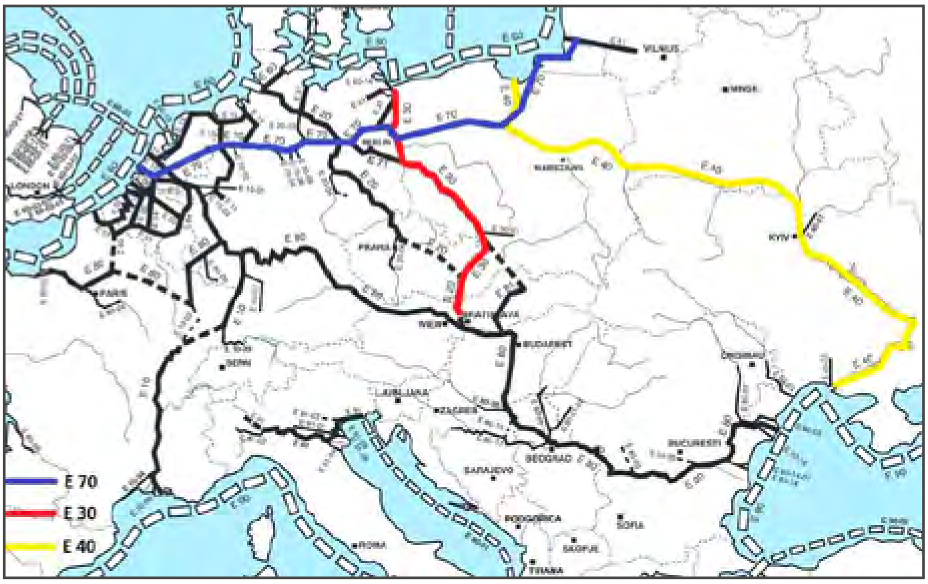
CHARACTERISTIC TECHNICAL SOLUTIONS OF BARRAGES PLANNED **ON THE VISTULA RIVER ON THE INTERNATIONAL E40 WATERWAY**

At the beginning of 2018, the Polish Senate unanimously passed a resolution on the government bill on the ratification of the European Agreement on Main Inland Waterways of International Importance (the AGN Convention) [1], drawn up in Geneva on January 19, 1996. Then the law was signed by the President of the Republic of Poland and communicated to the UN secretary.

The network of waterways of international importance – International Inland Waterways (IIW), included in the AGN Convention [1], has been divided into nine main water transport routes with a length of more than 27 thousand km, connecting the ports of 37 European countries. Three water routes run through the territory of Poland and they are:

1. IIW E40, connecting the Baltic Sea from Gdańsk and the Black Sea in Odessa.
2. IIW E30, running along the Odra River Waterway, connecting the Baltic Sea in Świnoujście and the Danube in Bratislava.
3. IIW E70, connecting the Oder and the Vistula Lagoon and forming part of the European east-west communication route connecting Klaipeda and Rotterdam.

Fig. 1. Schematic map of European inland waterways of international importance, detailing those running through Poland [4].



Pursuant to the Convention, the routes should be adapted to the IV class of navigability. Providing waterways with parameters of at least class IV, i.e., ensuring a transit depth of min. 2.8 m (max. draft 2.5 m) enables the use of TEN-T funds (EU Trans-European Transport Corridors). The next revision of the TEN-T network will take place in 2023. Until then, Poland must present ready and adopted programs for the reconstruction of waterways, which is currently being implemented by the Ministry of Infrastructure. The programs will be based on works carried out in recent years by the Port of Gdańsk Authority SA and the Szczecin and Świnoujście Seaports Authority SA.

The IIW E40 development program will be based on a completed study, entitled "Feasibility study for comprehensive international inland waterway management: E-40 for Vistula river between Gdansk and Warsaw, E-40 from Warsaw to the Poland-Belarus border (Brest) and E-70 between the Vistula river and the Vistula Lagoon (Elblag)" [3], completed in 2020 by Jacobs. It is currently owned by SWH Polish Waters. The course of IIW E40 assumes the use of mainly the Vistula riverbed, while its course from Warsaw to Brest was determined on the basis of a multi-criteria analysis based on technical, environmental, transport, economic, social and functional criteria. The routes of European IIW with plotted planned inland waterways routes of international importance running through the territory of Poland, i.e. E70, E30 and E40 are shown schematically in Fig. 1. Selected variant of the IIW E40 route is described later in this article.

OUTLINE OF THE CONCEPT OF THE INTERNATIONAL WATERWAY E40

The selected variant of the IIW E40 route, the route shown in Fig. 2, provides for the construction or reconstruction of approximately 726 km of inland waterway. Pursuant to the multi-criteria analysis performed as part of the study [3], the most preferred waterway route includes the following sections:

- Waterway on the Martwa Wisła River – from the seaport in Gdańsk to the Przegalina lock, approx. 27 km long;
- Waterway on the Vistula River from the junction with the Martwa Wisła to Dęblin, approx. 538 km long;
- an artificial shipping canal connecting the Vistula River (in Dęblin) and the Belarusian state border on the Bug River (in Brest), approx. 154 km long.

Within the construction of the Vistula River Waterway, the following are planned, among others:

- construction of 13 barrages with power-plants with a total capacity of approx. 625 MW, twin navigation locks and flowing water reservoirs. Location of the barrages is shown in Fig. 3;
- construction of a navigation lock at the junction of the Martwa Wisła and the Vistula River;
- reconstruction of four existing bridges, two of them on the E40 road (Sien-

Fig. 2. Planned route of the E40 waterway in the territory of Poland in accordance with stage III of the study [3].

Fig. 3. The planned route of the E40 waterway on the Vistula River in accordance with variant II of stage III of the study [3].

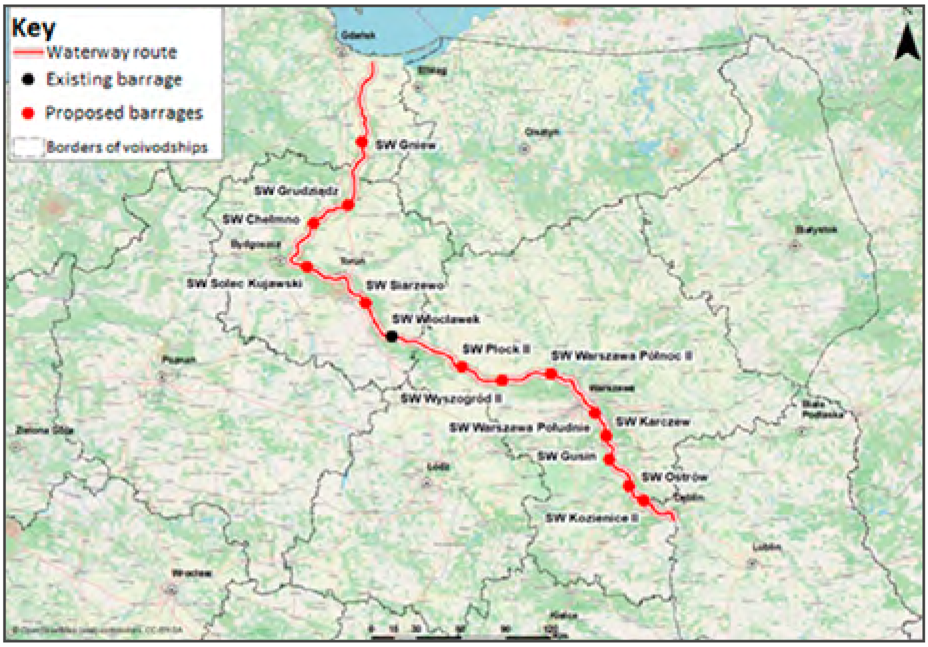
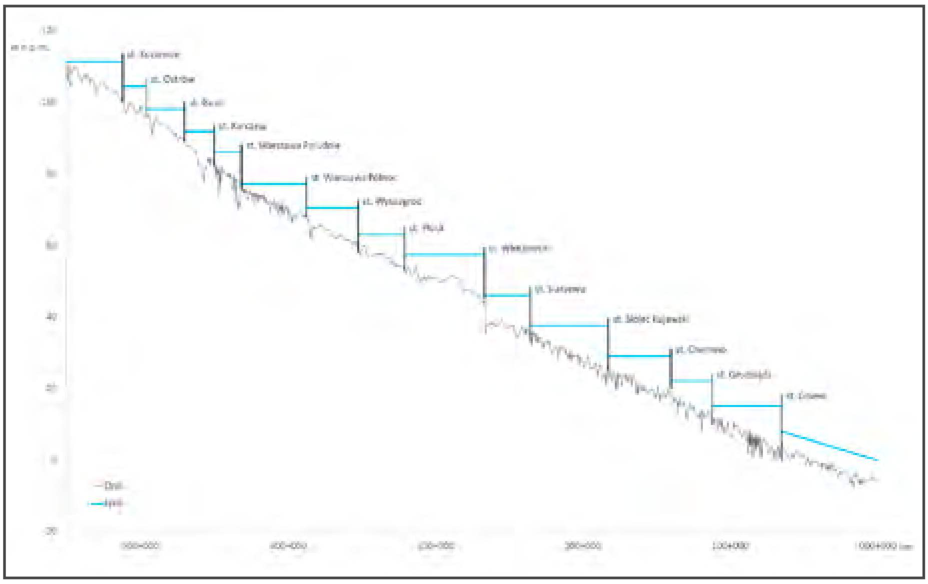


Fig. 4. Profile of the cascade of the planned barrages on the Vistula River within the E40 waterway [3].



nicki Bridge in Gdańsk, bridge over the Przegalina Lock);

- construction of 32 new road bridges, including 12 road crossings on barrages;
- construction of an artificial class Vb navigation canal, approximately 154 km long, with 5 double navigation locks (the purpose of the construction of the canal is to connect the Vistula River waterway and the inland waterways of Belarus in the Brest region, passing through a watershed, connecting the Vistula and Muchawiec valleys. It consists of the so-called branch rising towards the watershed and the summit site. The longitudinal profile of the canal is mainly determined by the shape of the existing terrain. Locally, its layout was also determined by collisions with the existing railway infrastructure and larger watercourses. Differences in levels between the sites are overcome by means of 5 navigation locks with different slopes. Navigability class Vb will be ensured along the entire route of the canal;
- construction of 2 railway bridges and a road tunnel along the route of an artificial navigation canal;
- construction of a retention reservoir in Kopytów with a pumping station supplying it with water.

IIW E40 on the section from the Port of Gdańsk to Dęblin (section on the Vistula)

On the IIW E40 section from Gdańsk to Dęblin, 14 barrages are planned, including the existing Włocławek Barrage. The location of the barrages is shown in Figure 3, and the cascade profile in Figure 4. The composition of all planned barrages will consist of the following elements:

- front dam,
- weir,
- water powerplant,
- shipping lock with avanports,
- port for icebreakers,
- technical fish ladders,
- road crossings (except for the Warsaw South barrage),
- bypass channel.

The basic parameters of weirs and flow-through reservoirs of the planned barrages are presented in Table 1, while the parameters of locks and water powerplants are presented in Table 2.

IIW E40 – section from Dęblin to Brest

The analysis gives three basic variants of the route connecting the Vistula and the exist-

Tab. 1. Parameters of barrages in the planned cascade – parameters of weirs and reservoirs.

Barrage	Location [km]	Damming height [m]	Weir parameters: Number of spans	Weir parameters: Span width [m]	Weir parameters: Ordinate of barrage [m n.Kr]	Reservoir parameters: Normal Head Water Level [m n.Kr]	Reservoir parameters: Top Water Level [m n.Kr]	Reservoir parameters: Capacity at Normal Head Water Level [mln m^3]	Reservoir parameters: Capacity at Top Water Level [mln m^3]
Gniew	876.300	7.20	16	20.00	6.00	15.00	15.50	b.d.[1]	b.d.[1]
Grudziądz	829.500	7.00	16	20.00	14.00	22.00	22.50	b.d.[1]	b.d.[1]
Chełmno	801.550	7.00	12	20.00	22.20	29.00	29.50	b.d.[1]	b.d.[1]
Solec Kujawski	758.000	8.50	12	20.00	30.70	37.50	38.00	b.d.[1]	b.d.[1]
Siarzewo[2]	706.380	8.30	15	25.00	38.40	46.00	46.50	135.40	151.20
Włocławek[3]	674.750	12.83	10	20.00	50.50	57.14	58.34	369.88	453.59
Płock II	617.900	7.75	15	25.00	56.00	63.00	79.04	65.10	149.87
Wyszogród II	585.000	8.48	15	25.00	63.50	70.50	138.77	71.80	193.49
Warszawa Płn. II	547.650	8.25	15	25.00	70.00	77.00	91.87	78.75	135.65
Warszawa Płd.	502.000	9.80	15	25.00	79.00	86.00	48.62	88.75	98.76
Karczew	482.800	6.90	15	25.00	84.80	91.80	47.55	93.05	70.43
Gusin	462.500	6.50	15	25.00	91.00	98.00	61.40	98.80	81.29
Ostrów II	435.000	8.45	15	25.00	97.30	104.30	106.45	33.24	71.54
Kozienice II	417.100	7.65	15	25.00	104.30	111.30	87.44	111.75	99.31

Tab. 2. Parameters of barrages in the planned cascade – parameters of locks and powerplants.

Barrage	Location [km]	Parameters of shipping locks: Effective width of the lock chamber [m]	Parameters of shipping locks: Effective length of the lock chamber [m]	Parameters of shipping locks: Depth at the bottom sill [m]	Parameters of water powerplants: Rated drop [m]	Parameters of water powerplants: SSQ [m^3/s]	Parameters of water powerplants: Q_{instal} [m^3/s]	Parameters of water powerplants: Power [MW]
Gniew	876.300	12.0	190.0	3.50	5.70	1075.00	1700.00	76.00
Grudziądz	829.500	12.0	190.0	3.50	4.00	1070.00	1800.00	56.50
Chełmno	801.550	12.0	190.0	4.00	8.00	1052.00	2350.00	68.00
Solec Kujawski	758.000	12.0	190.0	4.00	7.50	1014.00	2300.00	79.00
Siarzewo	706.380	12.0	190.0	b.d.	4.85	939.00	1800.00	80.00
Włocławek	674.750	12.0[4]	115.0[4]	1.10[5]	8.80	921.00	2190.00	160.20
Płock II	617.900	12.0	190.0	4.00	4.81	932.00	1118.40	42.22
Wyszogród II	585.000	12.0	190.0	4.00	6.49	888.00	1065.60	54.24
Warszawa Płn. II	547.650	12.0	190.0	4.00	5.61	606.00	727.20	32.00
Warszawa Płd.	502.000	12.0	190.0	4.00	5.71	575.95	691.20	31.00
Karczew	482.800	12.0	190.0	4.00	5.22	564.34	677.20	27.70
Gusin	462.500	12.0	190.0	4.00	5.00	563.19	675.80	26.50
Ostrów II	435.000	12.0	190.0	4.00	4.09	514.78	617.70	19.80
Kozienice II	417.100	12.0	190.0	4.00	6.62	507.15	608.58	31.63

[1] The parameters will correspond to Siarzewo Barrage.

[2] A new barrage is under construction on the Lower Vistula River below Włocławek.

[3] The existing barrage on the Lower Vistula.

[4] It is planned to build a second lock chamber with dimensions of 12 x 190 m, meeting the requirements for facilities for the minimum Vb class.

[5] After the construction of Siarzewo Barrage, the depth at the bottom sill of the Włocławek Barrage lock will be 3.50 m.

ing waterway in Belarus (Brest). Fig. 5 shows the course of the analyzed routes. The main purpose of the canal is to connect the Vistula River waterway and the Polish-Belarusian border, from which the class IV IIW is already constructed, enabling connection with the Black Sea. Currently, it is not rational to implement this connection with the use of natural watercourses, e.g., the Bug River. The final route of the canal and its shape were determined by many factors, i.a.:

- landform,
- interference in built-up areas,
- layout of protected areas,
- collisions with complexes and objects entered in the register of monuments.

The criterion that had a significant impact on the course of the canal concerned intersections / collisions with the existing watercourses. The shape of the longitudinal profile of the canal was determined especially by the size of the watercourses and their height location. The Dęblin – Brest canal was designed with the assumption of meeting the navigability class Vb requirement [2]. Structures enabling navigation in conditions corresponding to class IV and V of the waterway are classified as class II hydrotechnical structures[6] [7].

Shipping canal route and profile

The initial section of the route runs along the Wieprz River valley, then parallel to the Tyśmienica River and successively along the rivers: Stara Piwonia, Białka and Rudka. On the last section, the canal crosses the valleys of Żarnica, Zielawa, Lutnia, Werbia and Czapelka. The route of the canal and the location of shipping locks are shown in Fig. 6, and the canal profile is shown in Fig. 7. The canal runs in a trench and some sections in embankments due to the varying heights of the terrain and the necessity to overcome obstacles, especially where sections are adjacent to the planned navigation locks and where it crosses river valleys. The passage of the canal over the Bug River was planned in the form of a canal bridge. It was caused by very small depths in the riverbed, impossible to cross by units moving on international inland waterways. Increasing the transit depths in the Bug riverbed would require damming the water with a barrage located downstream Brest. This, in turn, would flood the Brest Fortress.

[6] Regulation [7] divides hydrotechnical structures on 4 classes. Assignment to specific class depends on structure's function and it's parameters, e.g. for structures connected with inland navigation assignment depends only on waterway class.

Fig. 5. Variants of IIW E40 routes on the section connecting the Vistula River and the Belarusian state border on the Bug River in Brest [6].

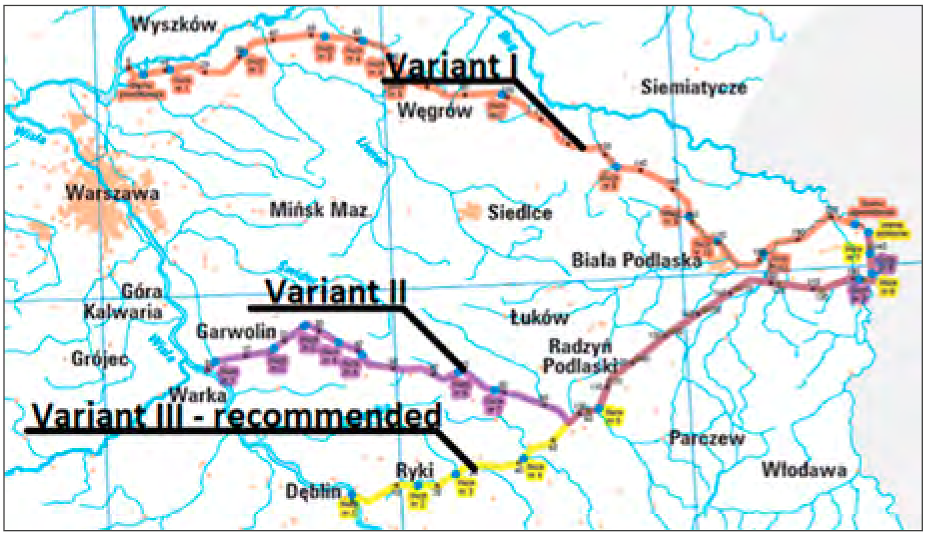


Fig. 6. Route of the planned Dęblin – Brest canal within the E40 waterway in accordance with stage III of the study [3].

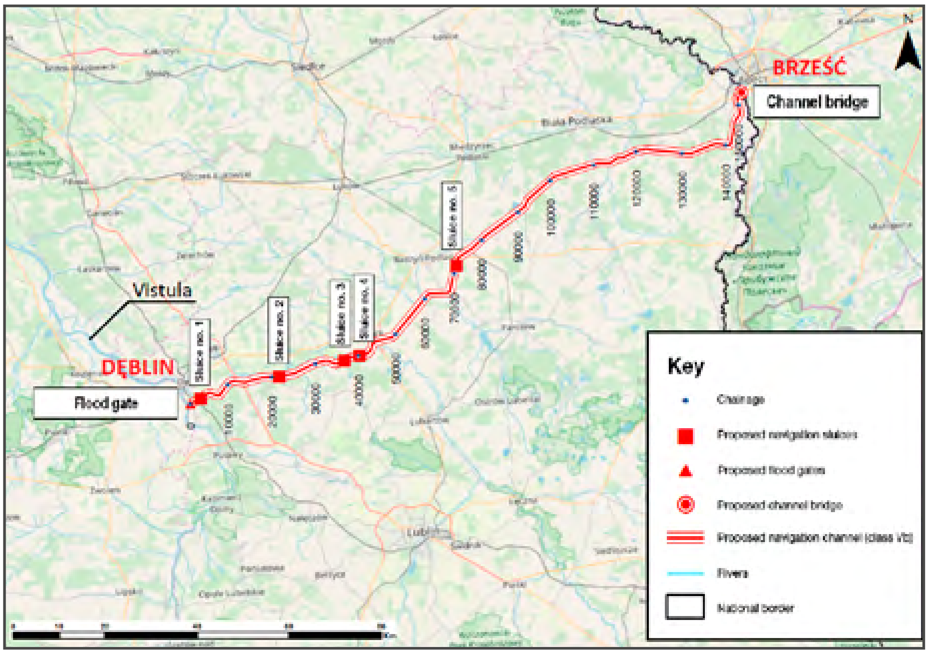
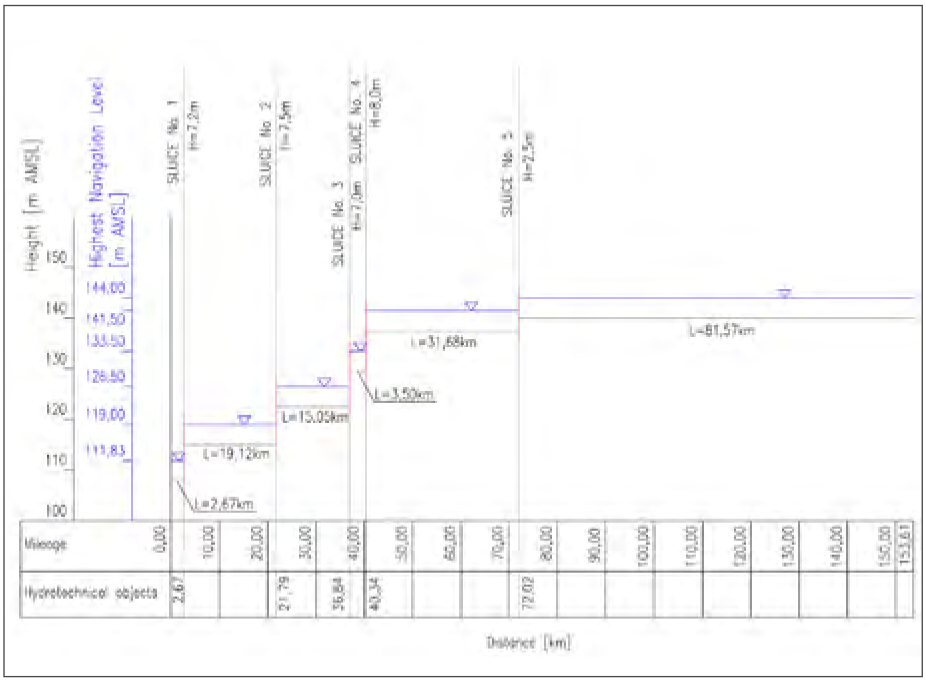


Fig. 7. Profile of the Dęblin-Brest canal [3], [8].



Shipping locks

The locks on the section of the navigation canal were designed to meet the operational parameters of the class Vb locks on the inland waterway. To overcome the difference in water levels on the canal, 5 twin, chamber shipping locks are provided, the parameters of them are summarized in Table 3.

UNIFICATION OF DESIGN SOLUTIONS FOR MODERN BARRAGES

Investments planned under IIW E40 will consider all socially and economically justified needs. In addition to the basic goal, water transport, they will also contribute to the improvement of Poland's water management and the rational management of the available water resources. The basis for development that SWH Polish Waters takes into account in a special way is the rational management of waters with the simultaneous use of them in an environmentally friendly manner.

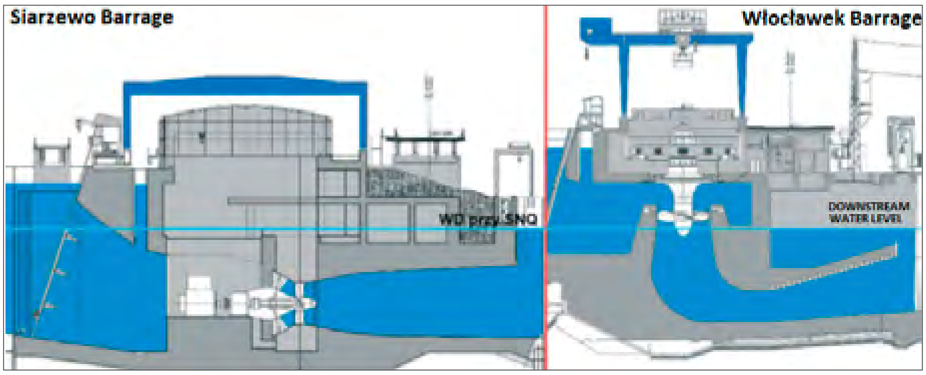
They are also intended to counteract the consequences of climate change, such as long periods of no rainfall leading to drought, or the effects of flooding caused by torrential rains. They will retain a significant percentage of the annual runoff, which is of great significance for the maintenance of biological life in the river during periods of low flows and for the water balance in the entire Lower and Middle Vistula Basin. Due to the draining nature of Polish rivers and the observed decrease in the level of water in rivers and groundwater, aggravated by bottom erosion, it is important to note the positive effect of raising and stabilizing water levels, both in rivers' beds and surrounding grounds. The powerplants planned at the barrages will ensure the production of green energy, generating about 5,000 GWh annually [9]. Water powerplants will ensure public safety, guaranteeing energy supplies in the event of the so-called blackout (failure of the power system). It is planned to use low-speed turbines with a horizontal axis (see Fig. 8). The planned investments will create conditions for water supply to adjacent areas, especially those that are endangered by drought (e.g., for agricultural use) and for use in industry.

It should be noted that when designing and building the barrages, the best available techniques are already used to reduce the negative environmental impact to an acceptable

Table 3. List of shipping lock parameters on the Dęblin-Brest canal.

Lock number	Kilometer of shipping route [km]	Height of the drop [m]	Total length of the lock [m]	Effective width of the chamber [m]	Effective length of the chamber [m]	Ordinate of the lower sill [m n.Kr.]	Ordinate of the upper sill [m n.Kr.]	Depth at the bottom sill [m]
1	2.673	7.2	218.0	12.0	190.0	107.83	115.0	4.0
2	21.795	7.5	218.5	12.0	190.0	115.00	122.5	4.0
3	36.846	7.0	217.7	12.0	190.0	122.50	129.5	4.0
4	40.346	8.0	219.3	12.0	190.0	129.50	137.5	4.0
5	72.025	2.5	212.7	12.0	190.0	137.50	141.0	4.0

Fig. 8. Cross sections of the powerplant through hydro-sets: planned facilities, as exemplified by Siarzewo Barrage with a turbine with a horizontal axis (on the left) and the existing Włocławek Barrage with a turbine with a vertical axis (on the right) [10].



minimum including controlled and minimalized impact on Natura 2000 areas and objects, a wide range of minimizing measures, a wide range of environmental compensation, e.g.:

- 584 ha, including: compensatory plantings of riparian forests below the designed water barrage on an area of 311 ha and within the reservoir above the water barrage on the area of 273 ha (including 127 ha of islands on the reservoir),
- 72 breeding boxes for Goosander and Shelduck,
- over 18 000 breeding boxes for cavity nesters,
- 15 islets on a new reservoir of 65 ha,
- 8 replacement ponds with an area of over 15 ha,
- patencing of damming the Mień river by constructing a gravel slope with a gravelly and rocky bottom; catching larvae of the river lamprey in the estuary stretch of the Mień River and moving them above the existing weir,
- patencing of damming threshold on the Zgłowiączka river,
- keeping a restocking the 'Drwęca River' with the fingerling of the Atlantic salmon, with at least 25.000 fish annually, for over the period of 5 years,
- setting up new trees – for 1 tree cut down, 10 newly planted trees,
- other solutions described in point 3.3.

Technical solutions also take into account the results of public consultations. To sum up, the facilities will be modern, pro-environmental and multifunctional, at the same time blending in with the surrounding landscape. The facilities will be with low damming sills, fulfilling many of the functions, ensuring the flow-like nature of the work and stabilizing the water level in the bed for low flows. The Siarzewo Barrage Project is an example of a modern barrage, currently implemented by SWH PW. It is planned at km 706 + 500 of the Vistula. It will be, following Włocławek Barrage, the second barrage on the Lower Vistula section. Although it is designed as a barrage that can work independently, in the future it will also be an indispensable element of the so-called Cascades of the Lower Vistula. Siarzewo Barrage will consist of such elements as: side dams, a weir, water powerplant, twin lock equipped with intermediate gates with upper and lower avanports, fish ladders for salmonids, sturgeon fish, eels, bypass channel – a natural fish ladder. The barrage is shown in Fig. 9. In the Program and Spatial Concept [15], several modern solutions have been assumed, they will also be applied at the other barrages, and ensure the achievement of all the goals while minimizing the negative impact on the environment. They are mainly: a weir with a low sill (Jambor-type sill) with segmented closures with a flap, a powerplant equipped with low-speed turbines with a horizontal axis and a bypass channel (semi-natural fish ladder).

Weir with a low Jambor-type sill

A weir with a low Jambor-type sill is a solution assumed in the project of the Siarzewo Barrage. Thanks to the small elevation of the sill above the existing bottom of the riverbed, with the simultaneous profiling of the sill's shape in the cross-section, not only is the hydraulic ability to pass water better, but also the possibility of flushing the accumulated sediment in the upper site (between the barrages), i.e., enabling transport. The Jambor-type sill will practically not cause flooding of the flood flow.

We are also planning to unify weirs and types of closures. Each of the planned barrages has a weir with a Jambor-type sill, segment closures with a flap, and the spans of the weirs are planned to be about 20 m wide. The number of spans will be based on a hydraulic analysis. The cross-section of the planned weirs along with a comparison to the structure of the Włocławek weir is shown in Fig. 10, and Figs. 11a and 11b show a diagram of the closures. The entire structure of the weir enables the passage of large and flood waters as well as sediment and ice in winter, stabilizing the water level in the period of medium and low flows [12].

Fig. 9. Composition of the Siarzewo Barrage [11].

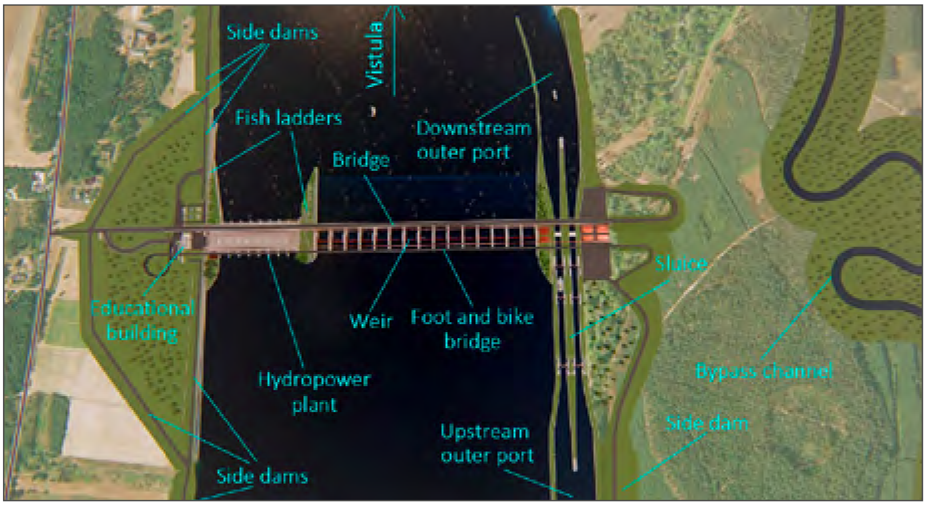
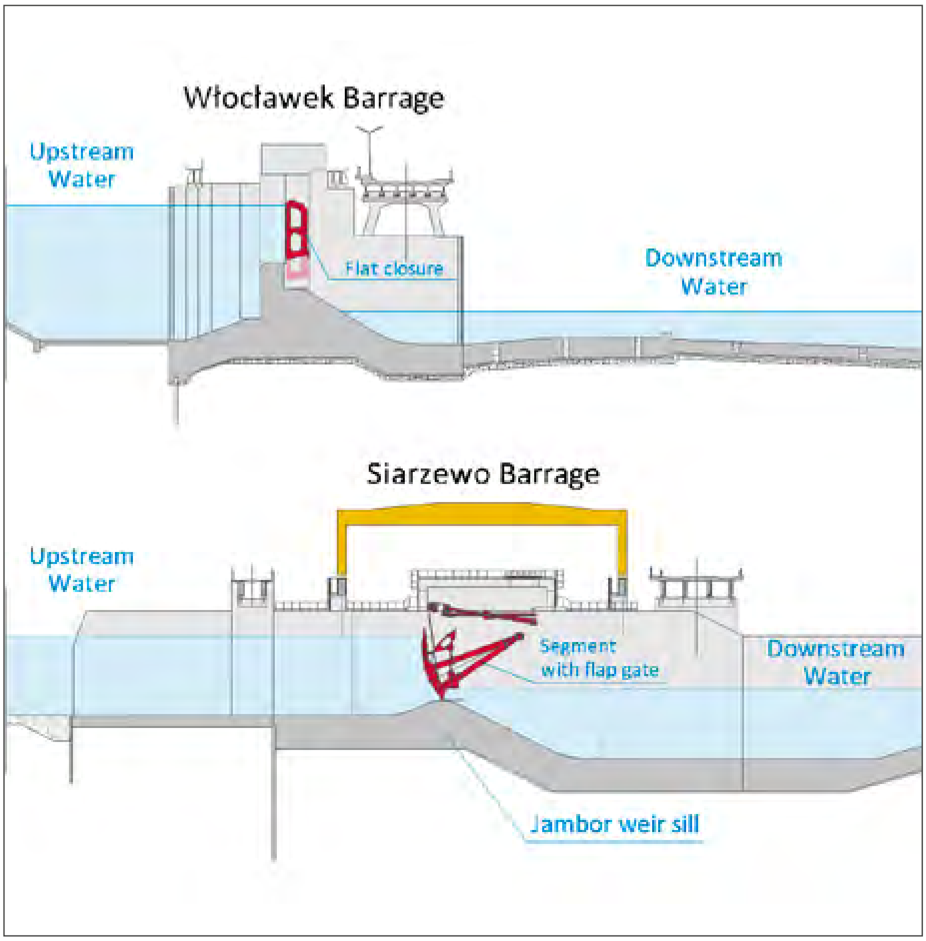


Fig. 10. Cross-sections of weirs: the existing one, i.e., Włocławek weir with a flat gate valve (top); planned as examplified by Siarzewo weir with a segmental closure with a flap (bottom) [8].



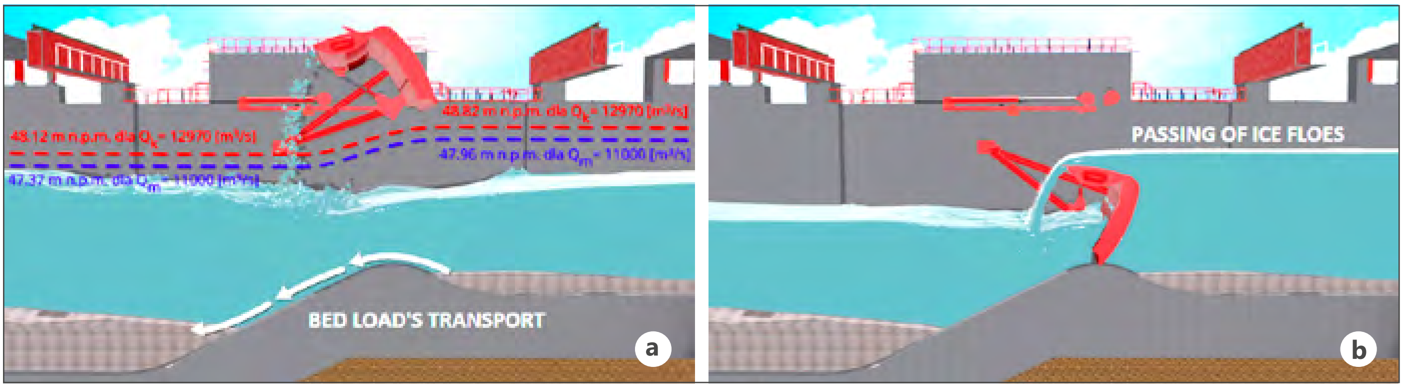
Floating ice floes

Virtually the entire Lower Vistula is threatened by floods caused by ice phenomena. Providing adequate depths for icebreakers and flaps mounted on segment closures for, inter alia, the safe floating of ice floes, shall eliminate the possibility of blockage floods on the section of the Vistula River to Włocławek. Stabilization of the water level will accelerate the formation of the ice cover (it will shorten the duration of unfavorable ice formation phenomena). Due to modern structure, the barrages will have greater possibilities to regulate the water flow, e.g., in winter, when the river carries a lot of ice floes, when there is a risk of winter floods.

Field fish ladder – bypass channel

The bypass channel will be a standard solution for all planned barrages, aimed at minimizing the impact on the environment by maintaining the functional continuity of the Vistula valley ecosystem, implemented by designing a natural riverbed and several activities in the newly created valley, resulting in the creation of a flood terrace and the creation of an ecological corridor. Expectations related to the implementation of this investment element include:

Fig. 11. (a) Sediment movement over of the elevation of the Siarzewo weir segment (b) Possibility of an ice floe passing at Siarzewo with a lowered segment [13].



- maintaining water flow enabling the free migration of fish and other aquatic organisms up and down the Vistula River throughout the year, with different water levels in the riverbed, related to the water levels in the Vistula River,
- ensuring the greatest possible number of fish species, both migratory and periodically undertaking compensatory migrations, the most effective overcoming of the obstacle, the water barrage,
- establishment of natural riverbanks, bottom and floodplain terraces along the riverbed, providing additional habitat sites for water-dependent ecosystems, including those enabling the restoration and proper functioning of valuable natural habitats that are subject to protection within the Natura 2000 area,
- creation of diversified river habitats ensuring high diversity and biomass of ichthyofauna, possible element of minimizing losses resulting from the construction of a new barrage.

Shipping lock

To ensure uninterrupted passage of floating objects through the barrages, it is planned to build locks with two chambers, meeting the requirements for this type of facilities for the minimum class Vb. Each chamber with dimensions of 12x190 m will be equipped with an intermediate gate, enabling the locking of units of various sizes, saving time, water, and energy. The modern solutions described above, planned to be used on planned barrages, had been assumed in the aforementioned Program and Spatial Concept of Siarzewo Barrage. Fig. 12 shows the above-mentioned solutions, as compared to the solutions used in Włocławek Barrage.

Comparison of basic technical parameters of Włocławek Barrage with planned barrages, as examplified by Siarzewo Barrage

Table 4 compares the basic parameters of the existing barrage in Włocławek and the planned barrages, as exemplified by the Siarzewo barrage.

Possibilities of adapting the Włocławek Barrage to the standards assumed for the barrages planned under IIW E40

The Barrage in Włocławek was constructed in 1962–1970. It was designed as the first one for the planned cascade of the Lower Vistula River. However, the construction of subsequent barrages was abandoned, and the Włocławek Barrage has been operating

Fig. 12. Top view of the existing Włocławek lock and the planned Siarzewo lock [8].

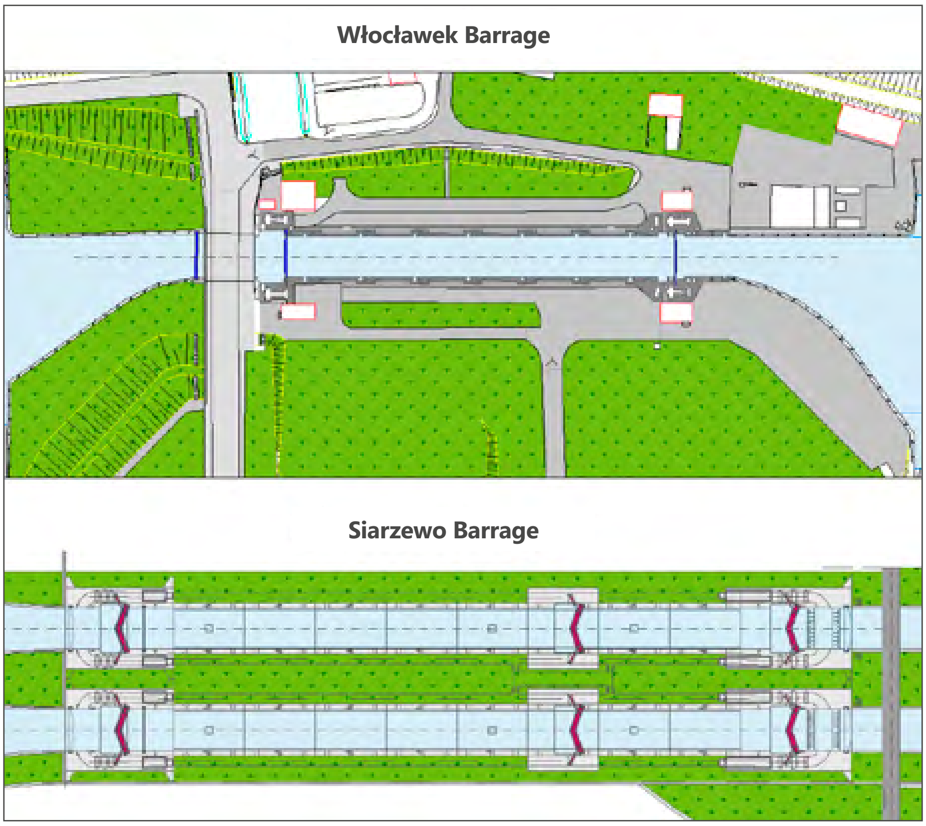


Table 4. Comparison of parameters of Włocławek Barrage and Siarzewo Barrage.

Description	[unit]	Włocławek	Siarzewo
Location	[km]	675	706
Year of construction	[year]	1970	2027
Elevation of the damming	[m above sea level]	57.3	46.0
Rated drop	[m]	8.80	4.85
Reservoir length	[km]	56.0	31.5
Approximate area of the reservoir at NPP	[km²]	75.0	27.5
Approximate static capacity at NPP	[million m³]	370	126
Number of drainage pumping stations	[pcs]	8	10
Length of side dams	[km]	28.9	20.5
Number of fish ladders	[pcs]	1	2
Bypass channel	[–]	No	Yes
Clear opening of the weir	[m]	200	360–375
Lock dimensions (length x width) and class	[m]	115 x 12 [IV]	2 x 190 x 12 [Vb]
Road crossing	[–]	Yes	Yes (it is to act as a technical route)
Number of hydro turbines	[pcs]	6	4
Turbine type	[type]	Kaplan	Kaplan
Installed discharge of water	[m³/s]	2 190	1 800
Installed power	[MW]	160.2	54–80
Average electricity production	[GWh/y]	739	375

for over 50 years in conditions inconsistent with the design assumptions, which resulted in, among others, great bottom erosion at the bottom site. Since the design of the Barrage in Włocławek, other standards have started to function in hydrotechnical construction. New construction materials began to be used and new rules were developed in the design of hydrotechnical structures. The barrage in Włocławek should be modernized to be adapted to the current environmental requirements, needs and rational water management, and above all to the needs of the planned IIW E40, mainly due to the lock that will be a bottleneck in river transport.

Adjustment of the lock parameters to the requirements of the planned waterway

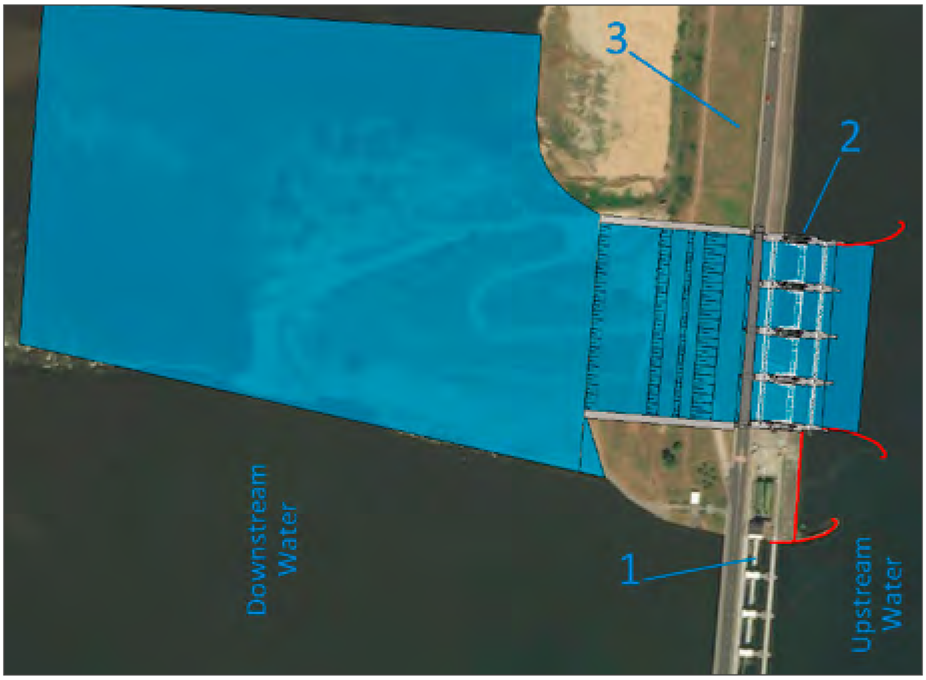
Execution of the E40 waterway is conditioned by the construction of new facilities enabling inland navigation on this section. In order to obtain fully correct functioning of the waterway, it is necessary to reconstruct the existing Włocławek Barrage so that it meets the parameters of IIW class Vb in accordance with the Regulation of the Council of Ministers of May 7, 2002 on the classification of inland waterways [2]. For this purpose, the existing lock should be adjusted to the appropriate parameters. The lock in Włocławek is insufficiently long – the current length is 115 m, while in the above – mentioned of the regulation [2], the minimum length of the navigation lock for class Vb is 187 m. To ensure the proper capacity of the waterway and the smoothness of the lock, it is necessary to rebuild the existing lock or construct a second lock chamber with parameters meeting the requirements. The construction of an additional chamber with parameters for class Vb and the maintenance of the existing lock seems to be a sufficient solution, at least for the forthcoming several dozen years. The concept of adapting the Włocławek lock to class Vb is shown in Fig. 13.

Table 5. List of parameters of the shipping lock Włocławek.

Shipping lock		Unit
Structure length	158.0	[m]
Effective length of the chamber	115.0	[m]
Effective width of the chamber	12.0	[m]
Height of the chamber walls	17.0	[m]
Ordinate of the bottom of the chamber	41.8	[m above sea level]

Fig. 13. Concept of rebuilding the Włocławek lock by adding a twin lock [8]; 1 – the existing lock chamber Włocławek; 2 – new lock chamber meeting the conditions for a waterway class Vb.

Fig. 14. Construction of additional spans with a low Jambor-type sill [8]; 1 – the existing spans of the Włocławek weir; 2 – additional spans of the weir with a Jambor-type sill; 3 – front dam.



Enabling the transport of sediment

One of the main problems related to the functioning of the Włocławek Barrage is the accumulation of river sediment at the upper site and erosion of the Vistula bed at the lower site. The construction of a barrage with a high-sill weir stopped the natural sediment transport process. The possibilities of solving the mentioned problems are specified below:

1. Reconstruction of some of the spans of the weir into low-sill spans or construction of new spans instead of an earth dam with a low sill, with segmental closures with a flap enabling the passage of sediment and floating ice floes (Fig. 14);
2. Construction of bottom outlets or bypass channels in the structure of the existing spans;
3. Cultivation of the sediment at the upper site and its hydrotransport to the lower site or transport of the sediment by barges.

It is currently difficult to assess which of the solutions would be the most effective and economically justified. This requires research and analytical work. It cannot be ruled out that all the potential solutions should be implemented.

Bypass channel of Włocławek Barrage

A technical fish ladder was launched at Włocławek Barrage in 1970. It was in a partition pillar between the weir and a hydroelectric hall. It was composed of 33 chambers (including 3 resting chambers) with a drop of 0.4 m between the chambers and the traditional design of alternate openings – overflow at the top (0.6x0.6 m), shed at the bottom (0.50x0.50 m) and the flow of 0.935 m³/s. The Technical Cooperation Program (TCP) with FAO (Food and Agriculture Organization of the United Nations) assumed the creation of the possibility of fish migration on Polish rivers, as part of which, in 2007, a con-

Fig. 15. Concepts of the route of the bypass channel of Włocławek Barrage [8].

cept for the enhancement of the Włocławek Barrage was developed – three projects were planned to be implemented – so far one of them has been implemented – in 2014, the existing fish ladder was reconstructed in order to adapt it to the new working conditions of the barrage.

Within the provisions of the Decision on Environmental Conditions for the planned Water Barrage in Siarzewo, there is a requirement to build a semi-natural bypass channel in Włocławek Barrage, adjusted with parameters to the needs of fish species, facilitating their migration. This is to create the best possible conditions for all ichthyofauna and minimize the negative impact on the environment. A new bypass of the dam in Włocławek would enable migrating fish to migrate to the Podkarpacie spawning grounds. The variants of the route of the Włocławek bypass channel are shown in Fig. 15, but the target route requires detailed analyzes. The negative impacts that have occurred so far, not only of a local dimension, but also of a wider range, should be significantly limited. The undertaking would modernize the existing barrage. It would positively affect the implementation of the international waterway E40.

SUMMARY

The planned E40 International Waterway, for which a program is currently being prepared by the Ministry of Infrastructure to be then subject to strategic environmental assessment, can be treated as a starting point for future hydrotechnical investments in the lower and middle section of the Vistula River. However, the entire project, as well as each individual facility, shall perform many tasks and meet, apart from shipping, other important goals, most of which shall be treated as overriding social goals, such as flood protection, drought mitigation, water supply, energy, tourism, and recreation, considering environmental requirements, some of which may be treated as environmental improvement objectives.

Multi-tasking of individual hydrotechnical facilities enabling sustainable water management is the common denominator for all investment activities planned by SWH Polish Waters, including the Vistula River section in question. Returning to the main topic of the article, i.e., IIW E40 is a significant issue that SWH Polish Waters considers a way to eliminate the "bottleneck" that is Włocławek Barrage. This goal is planned to be achieved by extending the existing lock (building a second chamber), however, taking into account the aforementioned multitasking and rational water management as well as minimizing the negative impact on the environment, it is necessary to develop solutions aimed at clearing the sill in terms of ensuring ecological continuity (bypass channel) and ensuring continuity of sediment flow by transporting sediment collected from the river / reservoir near Płock to the river downstream Włocławek Barrage. The areas should be the subject of research, study, and analysis soon.

PhD, Eng. Krzysztof Wrzosek
Warsaw University of Technology, WIBHiIŚ
State Water Holding Polish Waters

M.Sc., Eng. Przemysław Sobiesak
Eng. Grzegorz Sikorski
State Water Holding Polish Waters

Acknowledgments

The authors would like to express their gratitude to the Faculty of Studies, Analysis and Designs for Hydraulic Engineering, in particular Katarzyna Zagrobelna and Jakub Strzelecki.

Bibliography:

1. (1996) European Agreement on Major Inland Waterways of International Importance (AGN), done in Geneva on 19 January 1996.
2. (2002) Regulation of the Council of Ministers of May 7, 2002 on the classification of inland waterways.
3. Feasibility study for comprehensive international inland waterway management: E-40 for Vistula river between Gdansk and Warsaw, E-40 from Warsaw to the Poland-Belarus border (Brest) and E-70 between the Vistula river and the Vistula Lagoon (Elblag);
4. Wrzosek K. (2019) Presentation for the scientific and technical seminar entitled: Perspectives for the development of shipping on the Oder Waterway; SWH Polish Waters.
5. (2017) 5th International Maritime Congress in Szczecin, SWH Polish Waters. Own resources.
6. (2016) Expertise on the development of inland waterways in Poland for 2016–2020 with a perspective until 2030; Ministry of Maritime Economy and Inland Navigation, Warsaw.
7. (2007) Regulation of the Minister of the Environment of April 20, 2007 on the technical conditions to be met by hydrotechnical structures and where they are located.
8. SWH Polish Waters, Faculty of Studies, Analysis and Designs for Hydraulic Engineering. Own resources.
9. Król-Wojewódzka K., Rolbiecki R. (2017) Społeczno-ekonomiczne skutki zagospodarowania dolnej Wisły. [Socio-economic effects of the development of the lower Vistula.] 1st edition; Energa SA, Gdańsk, pp. 219–221.
10. (2018) Presentation of the Siarzewo Barrage Project developed as part of the work of the Technical and Organizational Working Group at the Steering Committee of the Siarzewo Barrage Project; Energa Invest Sp. z o.o., Gdańsk.
11. Bednarz K., Jurek K. (2020) Visualization of the Siarzewo Barrage, Faculty of Studies, Analysis and Designs for Hydraulic Engineering, SWH Polish Waters.
12. Gniedziejko I., substantive consultations: Wrzosek K., Puchała M., Sobiesak P. (2021) Dlaczego potrzebujemy stopnia wodnego w Siarzewie? Nowoczesne Budownictwo Inżynieryjne, [Why do we need a barrage in Siarzewo? Modern Civil Engineering], 96, pp. 30–31.
13. Bednarz K., Jurek K. (2020) Visualization of the operation of a weir, Faculty of Studies, Analysis and Designs for Hydraulic Engineering, SWH Polish Waters.
14. (2017) Decision of 29 December 2017 on environmental conditions for the Siarzewo variant of the project entitled: "Construction of a water barrage on the Vistula below Włocławek"; The Regional Directorate of Environmental Protection, Bydgoszcz.
15. (2018) Construction of a barrage on the Vistula below Włocławek. Program and Spatial Concept; Energa Invest Sp. z o.o., Gdańsk, SWH Polish Waters.
16. Woś K., Wrzosek K. (2021) The Siarzewo barrage: a key element in Poland's investment plans. The International Journal on Hydropower & Dams, 2, ss. 34–40, ISSN: 1352-2523
17. Wrzosek K., Jurek K., Górnik- Ziemkowska M., Sobiesak P., Puchała M. (2020) Siarzewo Barrage – Location and technical solutions. Gospodarka Wodna, 862, pp. 13–16, ISSN: 0017-2448
18. Kolerski T., Wrzosek K., Sobiesak P., Polak K. (2020) Mathematical modeling of ice transport within the planned Siarzewo Barrage. Gospodarka Wodna, 862, pp. 13–16, ISSN: 0017-2448
19. Dębowski P. (2015) Migracja ryb przepławką na stopniu wodnym we Włocławku w 2015 roku. Komunikaty rybackie [Fish migration through a fish ladder at the Włocławek barrage in 2015. Fishing Messages], 153, pp. 1–7.

AQUA TECH

MODERN SOLUTIONS
FOR WATER AND ENGINEERING CONSTRUCTION

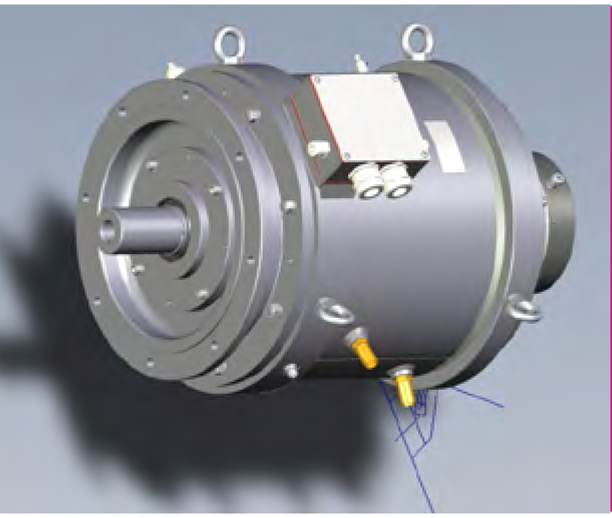
- ✓ modular small hydropower plants - design and construction
- ✓ autonomous weir closures of retention and drainage reservoirs
- ✓ flood protection systems river level monitoring
- ✓ innovative solutions for hydrotechnics

AQUA-Tech Sp. z o.o.
Lipcowa 64 32-540 Trzebinia

+48 530 133 269
+48 32 441 77 17

biuro@aqua-tech.info.pl

www.aqua-tech.info.pl
www.aquagen.pl



- ✓ synchronous generators (PMSG) for SHP
- ✓ hydroelectric sets for SHP for ultra-low-head locations
- ✓ modular control systems for SHP
- ✓ selection and modernization of SHP to the new technical guidelines

INNOVATIVE SOLUTIONS
FOR HYDRO POWER PLANTS

AQUA GEN

Fundusze Europejskie Inteligentny Rozwój
Rzeczpospolita Polska
Narodowe Centrum Badań i Rozwoju
Unia Europejska Europejski Fundusz Rozwoju Regionalnego

AQUA-Tech Sp. z o. o. is a beneficiary of the project POIR.01.02.00-00-0251 / 16 Development of a low-fall modular hydroelectric power plant technology with high energy efficiency and minimal environmental interference

TO EFFICIENTLY USE
THE POTENTIAL OF BESKO DAM

In the hydrographical network of Podkarpackie region, the lead role is occupied by water catchment areas of the rivers Wisłoka, San and Wisłok (do not confuse with the former). Even though in the context of hydroenergetics, the most recognizable object of this area is the dam on river San in the town of Solina, another damming structure of the region is definitely worth a closer look. The object is Besko Dam on the Wisłok river, and in the near future, another SHP object to dot the map of Poland shall be completed there.

The Wisłok river is the longest of the left-bank tributaries of the San river, measuring a total length of 204,9 km. In its upper course, it flows among densely forested hills of Beskid Niski (Low Beskid) and further on, through Jasielsko-Krośnieńska basin, Strzyżowskie, Dynowskie and Rzeszowskie foothills and via Podkarpacka urstromtal, to find its outlet in the vicinity of the town of Dębno. In the section examined within this article, the Wisłok is a small, flysch river with the average flow of 3.1 m³/s, while at the outlet section the flow increases to 24.5 m³/s.

Fig. 1. A view at the Besko Dam from the tailwater's side.

By the end of the 1970s (1978 to be exact) the Wisłok, similarly to many other rivers in that period, has been barricaded by a massive dam, what has led to the creation of artificial water reservoir, the Sieniawskie Lake, which is also called the Besko Reservoir – named after the town where the reservoir was originally planned to be located (it has finally been placed in the town of Sieniawa). The lake has an area of 1.31 km², minimal depth of 12 m, which reaches 30 meters at its maximum. It is primarily fed by the Wisłok river, but it is an outlet for two other streams – Odrzechowski and Głęboki. Primary functions of the Besko Reservoir (a.k.a.: Sieniawskie Lake) are – water retention and flood prevention in the Wisłok valley below the damming. The reservoir's existence allows for flow equalisation in the river that is characterised by a quick run-off – what causes flood waves to appear on the river several times a year. The water collected in the lake is used to supply drinking water to the population of such towns as Krosno, Sieniawa, Rymanów, Iwonicz-Zdrój and Brzozowo – it is also used to feed a fishing farm, and finally, the potential energy of the dammed waters is used to generate electricity.

THE OBJECT TO BE ADOPTED FOR THE PURPOSES OF ELECTRICITY GENERATION

The dam is situated at 172+800 km of the Wisłok river, its height is 38 m (the dam's crest is located at 338 meters ASL), it has a length of 174 m and there were 70 thousand cubic meters of concrete expended on its construction. The object is made with 14 independent dilated concrete sections that are sealed at dilations with PVC tape. Sections number 7 and 8 are longer than the remaining ones (they are 15 m long, the rest are 12 m) and serve overflow protection and drainage functions.

The Besko Dam is equipped with two bottom drains with hydraulically operated bolts with maximum water expenditure of 2×55 m³/s (110 m³/s in total). Inside the object there are two drainage control galleries that allow for functioning of control and measuring devices at the object. There are 2 pipelines with a diameter of 200 mm each that are destined for biological water flow, which ensure the biological flow to go into the lower sections of the Wisłok below the damming. These pipelines give us the opportunity to use the water that runs through them to generate energy. The original concept of building a SHP in the Besko Dam was conceived in the year 2003. Over the years the concept had been developed while waiting for stabilisation of the hydropower market conditions, so it can finally be completed and commissioned by the end of 2021. Curiously enough, the plant that is currently under construction is not the only object that draws from the energy generation potential of the dam. Since 1992 there is a SHP on the piping that is feeding raw water to the Sieniawa Water Purification Plant. The third object of this kind exists at the feed pipeline to the trout cultivation facility located 500 m below the body of the dam on the river's left bank.

SHP'S ARRANGEMENT AND EQUIPMENT

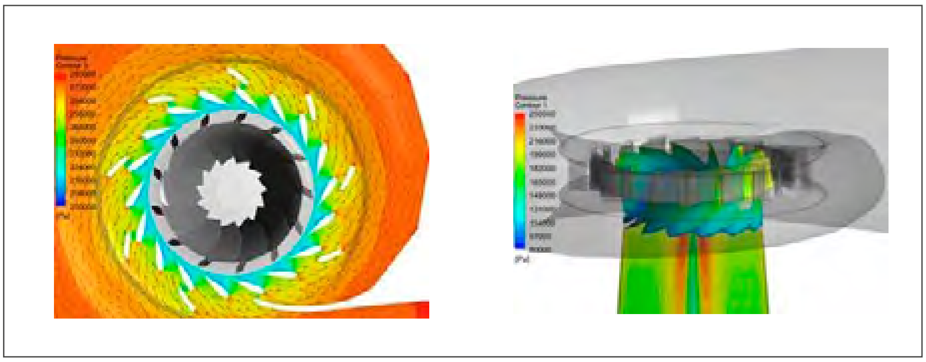
The construction project for the new powerplant assumes ensuring flow over the turbine through the biological flow pipelines that connect to each other in the drainage chamber to form a common piping serving as a turbine inlet. The hydroset shall have an installed power of 0,075 MW (75 kW) and will operate continuously over the head heights of 19 to 25 meters and flow rate of 0,3 m³/s. It shall be set-up in a layout with a horizontal shaft, the runner of the turbine will be placed in a helical feed inlet – the turbine shall have an external flow control actuation system and will be connected to an asynchronous generator. Everything shall be terminated with an outlet pipeline, allowing for the release of water back into the Wisłok just below the damming, within the stilling basin and sustaining the biological flow in the river. The SHP shall be connected to the existing electricity infrastructure, but it will be equipped with modern control system. The implementation of this project in the abovementioned form, apart from needing a professionally-made, detailed design documentation that could ensure efficient turbine operation, lack of pressure losses, elimination of the probability of cavitation – allowing for high hydraulic efficiency of the entire installation, and the best possible placement of all the components to allow for lengthy and reliable operation, also required a plethora of indirect actions. For that matter it is necessary to obtain: an environmental permit based on the technical concept, a decision on land development and management conditions as well as water permit and grid connection conditions. Even though SHP is being completely built within the premises of the existing infrastructure of Besko Dam, the investment's legal and formal preparatory works required obtaining a full set of the abovementioned administrative decisions.

MODERN AND HIGHLY EFFICIENT HYDROSET

Regarding the construction solutions within SHP Besko, there will be one turbine that will be fed through a steel helical inflow chamber. Straight suction pipe shall be attached using flange to the existing pipeline, and the turbine shall be connected to a generator via a transmissionless coupling. The entire hydraulic system has been individually designed and optimised to suit this particular use-case by R&D department of IOZE hydro. The first step to do it was to draw a two-dimensional design of a Francis turbine to serve as a base for creating its 3D model. Then the 3D model has been optimised using CFD simulation to enhance efficiency and decrease the chance for cavitation. ANSYS-CFX highly-specialised software has been used to perform the simulation. Owing to the individual design approach, a dedicated solution has been created – the one that fits perfectly with the local hydrological conditions. The efficiency of the turbine's hydraulic system has been designed to be around 94% under the optimal running conditions.

Transposition of these values from the digital world into the real one was done by creating all the key components of the turbine using multiaxial CNC machining devices. The perfect shaping of the designed turbine and its components, and above all the turbine's runner has a substantial impact on ability to reach maximum possible efficiency value while preventing the undesired phenomena, e.g. cavitation. Machining any components of water turbines demands precision and repeatability in creation of their complex geometry.

Fig. 2. Visualisation of a CFD simulation for a Francis turbine.



ADVANCED MANUFACTURING TECHNOLOGIES IN THE HANDS OF THE INVESTMENT'S CONTRACTOR

The runner of the Francis turbine, its guide vanes and cams of their actuators have been made with high-quality stainless steel by machining it on an OKUMA 5-axis multipurpose lathing and milling centre. This kind of a machine ensures an exact representation of a designed shape – its kinematic structure bolsters the device's stability, guaranteeing a desired accuracy and repeatability in detailing. The OKUMA machining centre is equipped with vibration dampening and temperature compensation systems that allow for achieving the desired values of surface roughness. In the context of using advanced technologies, it is worth mentioning that the preparatory works for the investment involved taking an inventory of the object's existing layout and its infrastructure. For this reason a detailed inventory has been created. It served as a basis for the detailed design documentation. As a part of the inventory-making detailed measurements of intake pipelines and outlet connection have been conducted. There was a significant difficulty in measuring the outlet connection and the outlet compensator, as both of these elements are located below the flooring, so it was necessary to use a laser scanning technology by employing a Faro Vantage laser tracker. This solution has been chosen on the grounds of the fact that the SHP equipment shall be embedded within the existing building and its internal layout, but there was no available realisation documentation. The contractor's engineers, using an array of laser tracked points to gather spatial data, have created a mapping of all the relevant spatial components with an accuracy of 0.016 mm/m. Highly sensitive technology has allowed to avoid any unpleasant surprises during the installation works.

COMPACT SOLUTIONS FOR SHPS

SHP Besko is an example of the object where the concept of compact solutions has been implemented. Installation of the key hydroset components, as well as testing it have been conducted at the production facility. Since the project's inception, at its every stage, including production, the goal was to minimise time necessary for installing and launching the electricity generation infrastructure at the installation destination. The devices that leave the production plant are ready-made modules available for quick and efficient installation within the existing construction infrastructure. IOZE hydro is a supplier of modern, efficient and high-quality water turbines.

Apart from traditional solutions, IOZE hydro also supplies compact SHPs to be either frame-mounted or in a form of a containerised unit. The target market of this product primarily lies abroad, where a significant factor that is decisive when it comes to the investment's execution is the scope of construction works required to place a hydroset at the destination. We invite all those who are considering implementing a modern turbine individually tailored to the object's needs, for an individual walkaround in our production facility. We will gladly show what the process of selecting, designing and producing hydrosets looks like at IOZE hydro.

IOZE hydro

Łukasz Kalina
Development Department
IOZE hydro

Photo and graphics come from the archive of **IOZE hydro**

Source: Real Moment, Adobe Stock

THE FUTURE OF HYDROPOWER – IEA SPECIAL MARKET REPORT

The growth of hydropower plants worldwide is set to slow significantly this decade, putting at risk the ambitions of countries across the globe to reach net-zero emissions while ensuring reliable and affordable energy supplies for their citizens. Forgotten giant of low-carbon electricity needs a sweeping policy and investment push to put it in line with net zero goals and to support a faster expansion of solar and wind, IEA special report shows.

Hydropower is the backbone of low-carbon electricity generation, providing almost half of it worldwide today. Hydropower's contribution is 55% higher than nuclear's and larger than that of all other renewables combined, including wind, solar PV, bioenergy and geothermal. In 2020, hydropower supplied 17% of global electricity generation, the third-largest source after coal and natural gas. Over the last 20 years, hydropower's total capacity rose 70% globally, but its share of total generation stayed stable due to the growth of wind, solar PV, coal and natural gas.

Emerging and developing economies have led global hydropower growth since the 1970s, mainly through public sector investments in large plants. Today, hydropower meets the majority of electricity demand in 28 emerging and developing economies, which have a total population of 800 million. In those countries, it has provided a cost-effective way to expand electricity access. In advanced economies, however, the share of hydropower in electricity generation has been declining and plants are ageing. In North America, the average hydropower plant is nearly 50 years old; in Europe, the average is 45 years old. These ageing fleets – which have provided affordable and reliable renewable electricity on demand for decades – are in need of modernisation to ensure they can contribute to electricity security in a sustainable manner for decades to come.

Hydropower plants also make a major contribution to the flexibility and security of electricity systems. Many hydropower plants can ramp their electricity generation up and down very rapidly compared with other power plants such as nuclear, coal and natural gas – and hydropower plants can also be stopped and restarted relatively smoothly. This high degree of flexibility enables them to adjust quickly to shifts in demand and to compensate for fluctuations in supply from other electricity sources. This makes hydropower a compelling option to support the rapid deployment and secure integration into electricity systems of solar PV and wind, whose electricity production can vary depending on factors like the weather and the time of day or year. With its ability to supply large amounts of low-carbon electricity on demand, hydropower is a key asset for building secure and clean electricity

Fig. 1. Low-carbon electricity generation by technology, 2020.

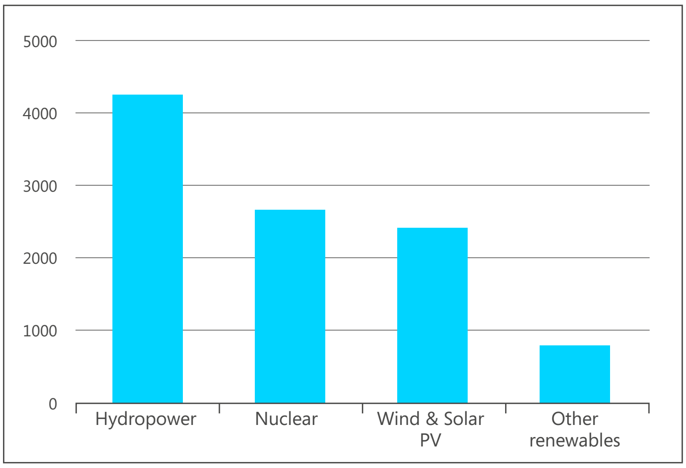
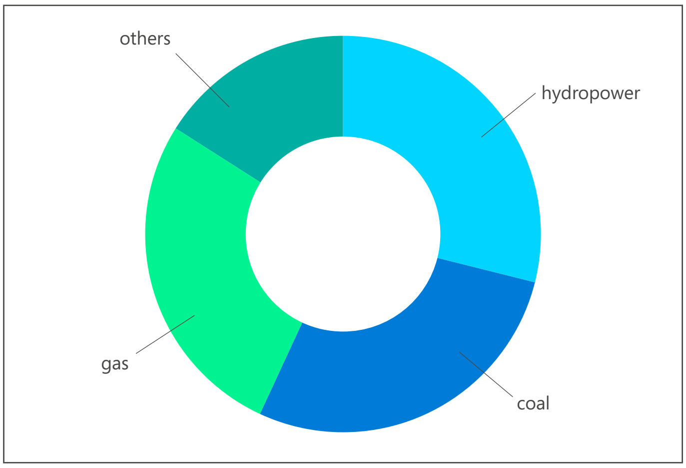


Fig. 2. Share of flexible power capacity by source, 2020.



systems. Today, hydropower plants account for almost 30% of the world's capacity for flexible electricity supply, but they have the potential to provide even more.

UNLOCK HYDROPOWER'S HUGE POTENTIAL

Globally, around half of hydropower's economically viable potential is untapped. The potential is particularly high in emerging economies and developing economies, reaching almost 60%. Over the life cycle of a power plant, hydropower offers some of the lowest greenhouse gas emissions per unit of energy generated – as well as multiple environmental benefits.

Governments have an important role in ensuring hydropower's potential is realised sustainably. Robust sustainability standards and measures are needed to increase investor confidence and gain public acceptance. Today, environmental assessments of hydropower plants can be very long, costly and risky, which can deter investment. Therefore, hydropower projects need to meet clear and widely accepted sustainability standards in order to make them viable. Ensuring that hydropower projects adhere to strict guidelines and best practices can minimise sustainability risks while maximising social, economic and environmental advantages. This approach also reduces lead times for projects.

REVENUES VISIBILITY – KEY TO ATTRACT INVESTMENT

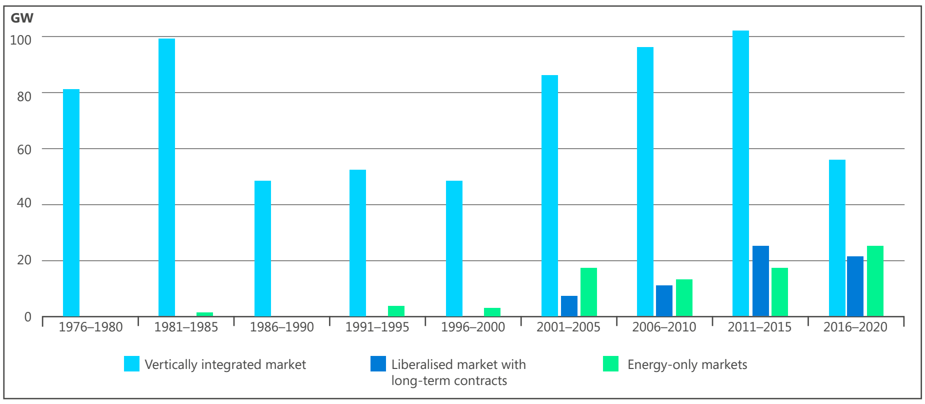
Policy measures that provide more certainty on future revenues can reduce investment risks and ensure the economic viability of hydropower projects. Since the 1950s, more than 90% of hydropower plants have been developed under conditions providing revenue certainty through power purchase guarantees or long-term contracts. This has happened in both vertically integrated and liberalised electricity markets. Today, challenges concerning complex permitting procedures, environmental and social acceptance, and long construction periods can lead to higher investment risks. In advanced economies, the business case for hydropower plants has deteriorated due to declining electricity prices and lack of long-term revenue certainty. Long-term visibility on revenues, especially for large-scale hydropower projects with long lead times, reduces financing costs significantly and increases project viability, thereby facilitating investment. This is particularly important when the private sector is involved.

MAJOR POLICY CHANGES NEEDED

Global hydropower capacity is set to increase by 17%, or 230 GW, between 2021 and 2030. However, net capacity additions over this period are forecast to decrease by 23% compared with the previous decade. The contraction results from slowdowns in the development of projects in the People's Republic of China ("China"), Latin America and Europe. However, increasing growth in Asia Pacific, Africa and the Middle East partly offsets these declines. The IEA is providing the world's first detailed forecasts to 2030 for three types of hydropower: reservoir, run-of-river and pumped storage plants. Reservoir hydropower plants, including dams that enable the storage of water for many months, account for half of net hydropower additions through 2030 in our forecast. Cost-effective electricity access, cross-border export opportunities and multipurpose use of dams are the main drivers of the expansion of reservoir projects. Pumped storage hydropower plants store electricity by pumping water up from a lower reservoir to an upper reservoir and then releasing it through turbines when power is needed. They represent 30% of net hydropower additions through 2030 in our forecast. The increasing need in many markets for system flexibility and storage to facilitate the integration of larger shares of variable renewables drives record growth of pumped storage projects between 2021 and 2030. Run-of-river hydropower – which generates electricity through natural water flow with limited storage capability – remains the smallest growth segment because it includes many small-scale projects below 10 MW.

China is set to remain the single largest hydropower market through 2030, accounting for 40% of global capacity growth in our forecast. However, China's share of global hydropower additions has been declin-

Fig. 3 Gross hydropower capacity additions by market type, 1976–2020.



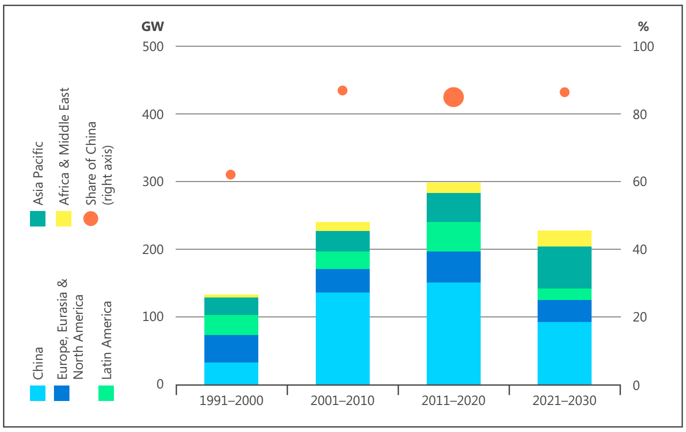


Fig.4 Global net hydropower capacity additions by region, 1991–2030.

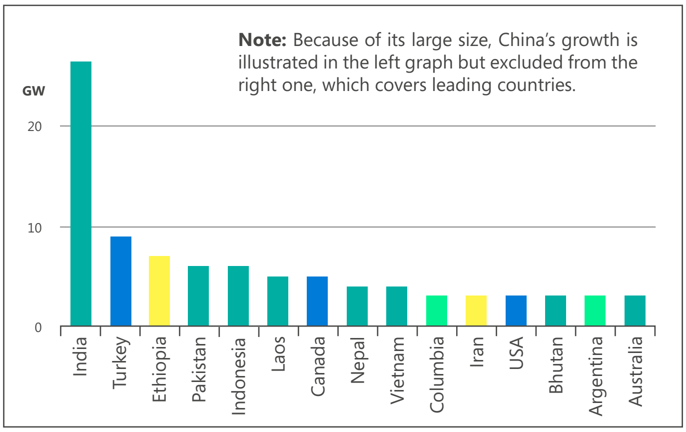
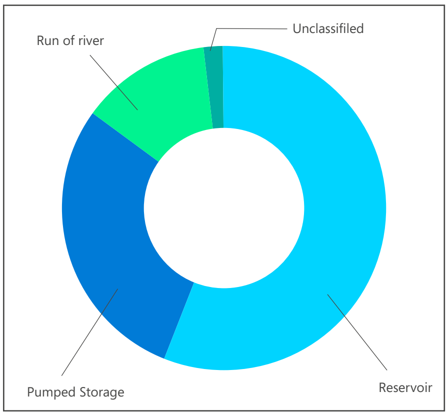


Fig. 5 Global net hydropower capacity additions by leading countries, 2021–2030.

ing since its peak of almost 60% between 2001 and 2010. China's pace of hydropower development has slowed due to growing concerns over environmental impacts and the decreasing availability of economically attractive sites for large projects. In India, the world's second-largest growth market, new long-term targets and financial incentives are expected to unlock a large pipeline of previously stalled projects. Growing electricity demand and export opportunities are driving faster hydropower expansion in Southeast Asia and Africa. The Lao People's Democratic Republic ("Lao PDR") and Nepal are developing projects for exporting electricity. Sub-Saharan Africa is expected to record the third-largest growth in hydropower capacity over the next decade, owing to large untapped potential and the need to increase electricity access at a low cost. Hydropower development in Brazil, which has historically driven the expansion of capacity in Latin America, has slowed because of the limited availability of economically viable sites, the need for diversification, and environmental concerns. Going forward, Colombia and Argentina are set to lead hydropower growth in Latin America. Turkey's hydropower development, which already has strong momentum, is expected to drive the largest expansion in capacity in Europe over the coming years. And in North America, electricity export opportunities are set to spur moves to realise some of Canada's untapped hydropower potential.

Fig. 6 Net hydropower capacity additions by technology segment, 2021–2030.



CHINESE INVESTMENTS IN EMERGING AND DEVELOPING ECONOMIES

Over half of all new hydropower projects in sub-Saharan Africa, Southeast Asia and Latin America through 2030 are set to be either built, financed, partially financed or owned by Chinese firms. China's role in hydropower development is largest in sub-Saharan Africa, where it is expected to be involved in nearly 70% of new capacity between now and 2030. This includes the largest hydropower project currently under construction on the continent, the Grand Ethiopian Renaissance Dam. In Asia, excluding India, nearly 45% of all hydropower plant capacity that is set to be built through 2030 involves a Chinese company. Pakistan and Lao PDR are expected to see the largest Chinese contributions in the form of financing or construction. In Latin America, over 40% of hydropower expansion is forecast to have Chinese involvement, including notable investments in Argentina, Colombia and Peru. More broadly, over 75% of new hydropower capacity worldwide through 2030 is expected to come in the form of large-scale projects in Asia and Africa commissioned by state-owned enterprises. In vertically integrated and single-buyer markets – in China and Africa, for example – the role of the public sector remains dominant. In Latin America and Europe, some countries provide support policies like auctions and feed-in tariffs (FiTs) that lead to higher shares of private sector investment in hydropower plants.

THE MODERNISATION OF AGEING HYDROPOWER PLANTS

Between now and 2030, USD 127 billion – or almost one-quarter of global hydropower investment – will be spent on modernising ageing plants, mostly in advanced economies. Work on existing infrastructure – such as the replacement, upgrade or addition of turbines – will account for almost 45% of all hydropower capacity installed globally over the period. In North America and Europe, modernisation work on exisiting plants is forecast to account for almost 90% of total hydropower investment this decade. Overall, this spending on modernising plants helps global hydropower investment to remain stable compared with last decade.

However, projected spending on existing plants is not enough to meet the global hydropower fleet's modernisation needs. By 2030, more than 20% of the global fleet's generating units are expected to be more than 55 years old, the age at which major electromechanical equipment will need to be replaced. This offers an excellent opportunity to increase the flexibility capabilities of ageing plants. The modernisation of all ageing plants worldwide would require USD 300 billion of investment between now and 2030 – more than double the amount we currently expect to be spent on this. The limited visibility on long-term revenues and the major investments needed to replace equipment can make it difficult to secure the necessary financing. The contractual arrangements and ownership model of each hydropower plant will be key factors in determining whether and when modernising the plant is bankable.

RISING LEVELS OF WIND AND SOLAR PV IN ELECTRICITY SYSTEMS

The flexibility and storage capabilities of reservoir plants and pumped storage hydropower facilities are unmatched by any other technology. Higher shares of variable renewables will transform electricity systems and raise flexibility needs. With low operational

Fig. 7. China's role in owning, constructing, developing and financing hydropower project capacity, 2021–2030.

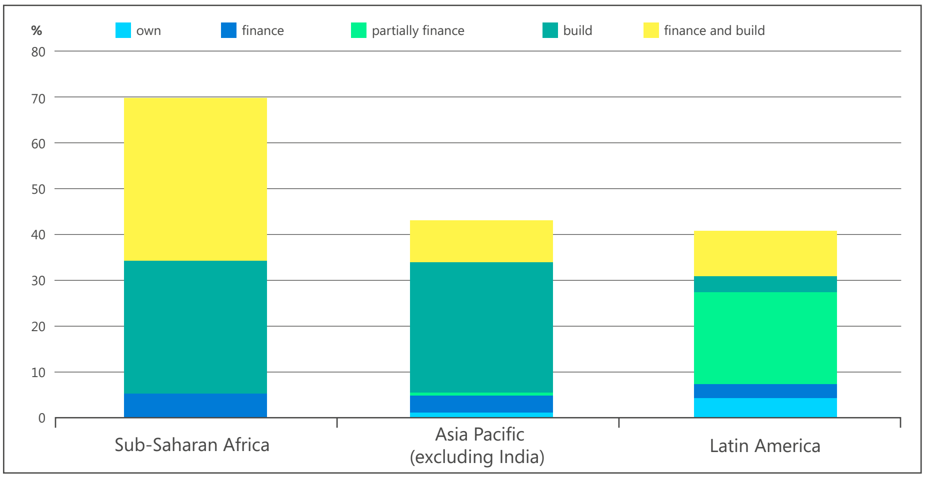
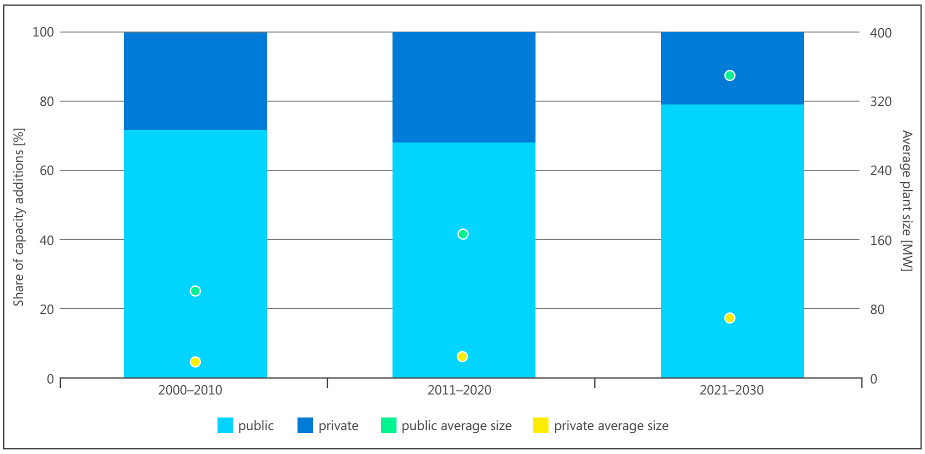


Fig. 8. Sector share of hydropower capacity additions and average plant size, 2000–2030.



costs and large storage capacities, existing reservoir hydropower plants are the most affordable source of flexibility today. For the first time, the IEA has estimated the enormous energy value of water stored behind hydropower dams worldwide. The reservoirs of all existing conventional hydropower plants combined can store a total of 1 500 terawatt-hours (TWh) of electrical energy in one full cycle – the equivalent of almost half of the European Union's current annual electricity demand. This is about 170 times more energy than the global fleet of pumped storage hydropower plants can hold today – and almost 2 200 times more than all battery capacity, including electric vehicles.

Pumped storage hydropower plants will remain a key source of electricity storage capacity alongside batteries. Global pumped storage capacity from new projects is expected to increase by 7% to 9 TWh by 2030. With this growth, pumped storage capacity will remain significantly higher than the storage capacity of batteries, despite battery storage (including electric vehicles) expanding more than tenfold by 2030. In addition to new pumped storage projects, an additional 3.3 TWh of storage capability is set to come from adding pumping capabilities to existing plants.

Developing a business case for pumped storage plants remains very challenging. Pumped storage and battery technologies are increasingly complementary in future power systems. Each offers cost-effective storage solutions for different timescales. However, as pumped storage plants are larger and more capital-intensive, investment in them is viewed as riskier than battery projects and is not always adequately remunerated. The economic attractiveness of new pumped storage investments is weakened by a lack of long-term remuneration schemes, low prices for flexbility services, and uncertainty over electricity prices and market conditions.

BARRIERS HAMPERING FASTER DEPLOYMENT OF HYDROPOWER

New hydropower plants can provide a critical source of cost-effective and flexible low-carbon electricity. Prior to the massive cost declines of solar PV and wind, hydropower was the most competitive renewable electricity source globally for decades. Compared with other renewable options and fossil fuels, developing new large-scale hydropower plants remains attractive in many developing and emerging economies in Asia, Africa and Latin America where there is still significant untapped hydropower potential to supply flexible electricity and meet increasing demand. New pumped hydropower projects offer the lowest-cost electricity storage option. Greater electricity storage is a key element for ensuring electricity security and a reliable and cost-effective integration of growing levels of solar PV and wind.

However, the hydropower sector has a number of challenges that hamper faster deployment. New hydropower projects often face long lead times, lengthy permitting processes, high costs and risks from environmental assessments, and opposition from local communities. These pressures result in higher investment risks and financing costs compared with other power generation and storage technologies, thereby discouraging investors. In emerging and developing economies, where the largest untapped potential for new hydropower lies, the attractiveness of hydropower investments is impacted by economic risks, concerns about the financial health of utilities and policy uncertainties. In advanced economies, current market designs often do not support the business

Fig. 9. Actual vs required investment needs for modernisation of plants by region, 2021–2030.

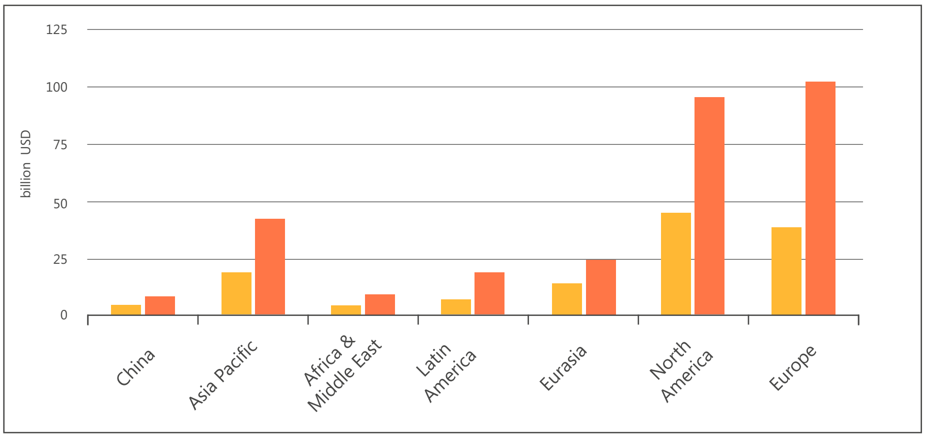


Fig. 10. Global energy and electricity storage capabilities by technology, 2020.

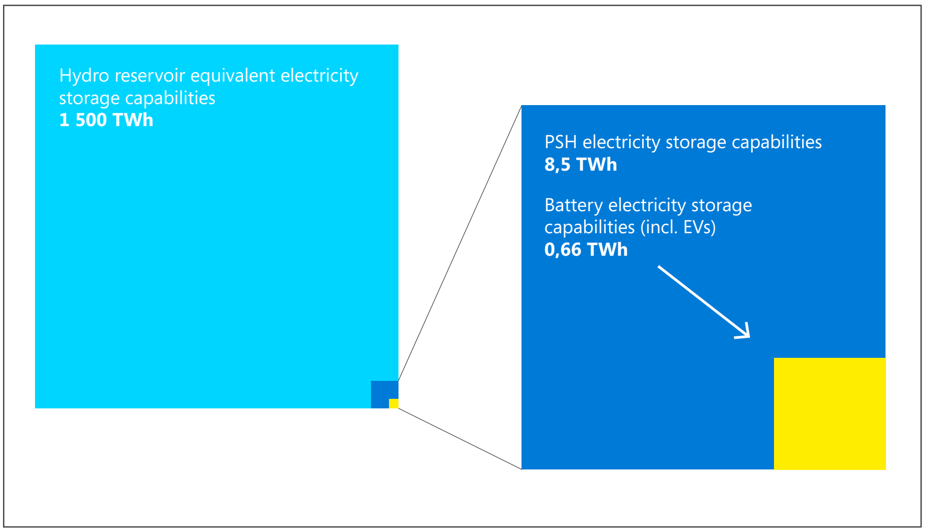
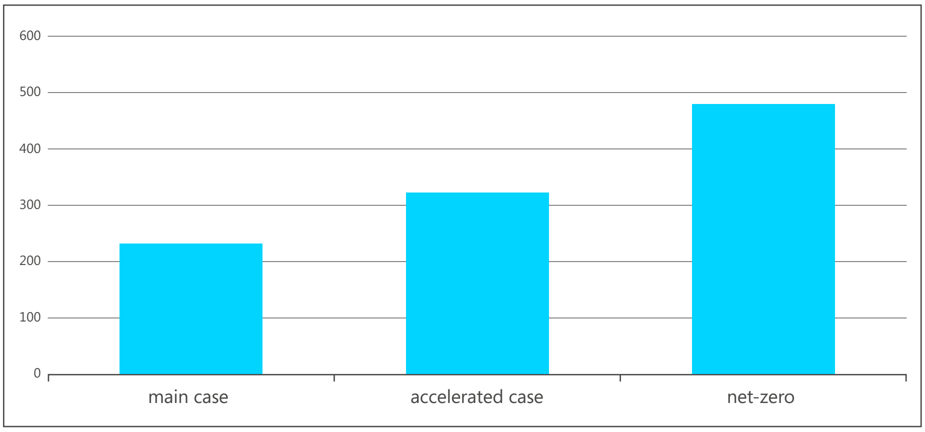


Fig. 11. Net hydropower capacity additions over 2021–2030, by scenario.



case for pumped storage plants, and there is a lack of incentives to modernise ageing fleets. Policy support remains limited, with less than 30 countries targeting hydropower. The public sector owns and operates 70% of all hydropower capacity installed globally between 2000 and 2020. Historically, its extensive involvement in developing hydropower plants has ensured adequate remuneration and profitability in the context of long-term energy planning. Today, when the private sector is involved, well-designed government policies are crucial for reducing risks related to permitting, construction and environmental and social acceptance challenges. Beyond electricity supply, hydropower infrastructure enables multiple benefits for managing water resources needed for critical public services such as such as irrigation, flood prevention and water supplies. Acknowledging these advantages and attributing monetary value to them can significantly enhance the business case for hydropower.

POLICY ATTENTION NEEDED TO MEET NET-ZERO EMISSIONS GOALS

If governments address the hurdles to faster deployment appropriately, global hydropower capacity additions could be 40% higher through 2030, according to the accelerated case we developed for this report. In emerging and developing economies, faster growth would be possible with increased access to concessional financing and the introduction of innovative business models such as public-private partnerships that allocate risk to the appropriate stakeholder. In addition, faster growth could be possible if project delays due to environmental and social concerns are kept at a minimum through streamlining approval processes, notably in Asia and Latin America. In advanced economies, modifying market designs or introducing policies that provide revenue certainty could boost growth for pumped storage projects. All of these efforts to accelerate deployment would still need to be carried out in a manner that maintains high sustainability standards.

Reaching net-zero emissions by 2050 worldwide calls for a huge increase in hydropower ambitions. Our accelerated case provides an outlook for faster hydropower expansion based mostly on implementation improvements. But to put the world on a pathway to net zero by 2050, as set out in the IEA's recent Global Roadmap, governments would need to raise their hydropower ambitions drastically. In fact, the expansion of global hydropower capacity through 2030 would need to be 45% higher than in our accelerated case.

International Energy Agency

Graphics come from Hydropower Special Market Report – Analysis and forecast to 2030, IEA 2021

The IEA's 7 priority areas for governments to accelerate hydropower growth

1. Move hydropower up the energy and climate policy agenda
2. Enforce robust sustainability standards for all hydropower development with streamlined rules and regulations
3. Recognise the critical role of hydropower for electricity security and reflect its value through remuneration mechanisms
4. Maximise the flexibility capabilities of existing hydropower plants through measures to incentivise their modernisation
5. Support the expansion of pumped storage hydropower
6. Mobilise affordable financing for sustainable hydropower development in developing economies
7. Take steps to ensure to price in the value of the multiple public benefits provided by hydropower plants

Water Turbines Works

................we believe in the power of nature

WTW Poland sp. z o.o. is a leading Polish manufacturer of water turbines as well as mechanical and electrical equipment for Small Hydroelectric Power Plants. We have been present on the Polish market since 1989 and so far we have produced 209 turbines with a capacity of> 15.5 MW. Our turbines also work in Italy, Estonia, Ukraine, Belarus and Germany. We provide high efficiency of turbines, professional advice on the selection of devices for a specific location, as well as warranty and post-warranty service. We design and supply Kaplan turbines for heads from 1.5 m to 24 m in many different configurations. Please visit our website where detailed information about our offer is available.

SHP Glebocko, Poland

6x136 kW (d=1090mm, H=3.1m)

SHP San Secondo, Italy

1x92 kW (d=720mm, H=5.4m)

SHP Naviglio, Italy

1x84 kW (d=560mm, H=7.6m)

SHP Chancza, Poland

1x177 kW (d=590mm, H=11.9m)

+48 695 639 657

info@wtw-poland.com

ul. Konopnickiej 2 F
11-200 Bartoszyce, POLAND

www.wtw-poland.com

Source: PKN ORLEN S.A.

HYDROPOWER POTENTIAL LIES ALSO **IN SEWAGE SYSTEMS**

The constant increase in the demand for electricity on a global scale, along with the need to reduce CO_2 emissions, encourages the improvement of energy efficiency and the transition to a circular economy. One of the ways to do this is to use the energy potential of municipal and industrial installations in which it is possible to recover energy that is initially dissipated at a loss. Facilities of this type open up completely new development opportunities for the hydropower industry.

The economic development of the world and the increase in the number of the Earth's inhabitants significantly increased the demand for energy, but also caused the depletion of natural resources. United Nations forecasts (based on the Food and Agriculture Organization (FAO) and the World Water Council) assume that the world's population will increase by 1/3 until 2050, which will translate into a 50% increase in water demand (as well as increased volume of discharged wastewater) and energy in this period. Currently, the vast majority of energy (about 2/3 of the world structure and consumption by carriers) is produced from fossil fuels. Its production causes the emission of harmful substances to the environment.

SUSTAINABLE ECONOMY IN THE EU

In the era of climate change, the production of energy, low–, zero-emission and green energy from renewable sources is becoming a very important issue. In particular, the European Union, wishing to be a leader in action to combat climate change, adopted an action plan for a sustainable EU economy called the "European Green Deal" (EGD), in which more efficient use of resources thanks to the transition for a clean circular economy (Circural Economy) is emphasized.

The purpose of the EGD is to counteract the loss of biodiversity and reduce the pollution level. Thus, energy efficiency is also becoming an important issue. Reducing the unit demand for energy leads to real progress, without forcing to reduce the scale of production, giving the possibility of development and allowing to reduce costs, including environmental costs. On January 23, 2008, the European Commission presented a package of documents, mainly legislative, referred to as the so-called energy and climate package. These documents were aimed at the implementation of the assumptions adopted by the European Council in 2007 concerning counteracting climate change. These regulations state that by 2020 the European Union [1] will, inter alia: increase the share of renewable energy in final energy consumption by 20%, increase energy efficiency by 20%, compared to the forecasts for 2020. On October 23, 2014 in Brussels, during the summit, the leaders of the European Union Member States agreed on the EU climate policy goals for 2030. The target for improving energy efficiency was agreed, defined as a 27% reduction in demand in relation to forecasts and achieving at least 27% share of renewable sources in total energy consumption. Also, legal regulations, such as Directive 2006/32/EC, as amended, required a gradual reduction of final energy consumption by 1% annually, starting from 2008 [1, 2]. One cannot forget here about the Reference Document on Best Available Techniques (BAT) in the field of Energy Efficiency of February 2009 – ENE BREF [1, 2].

WORLD HYDROPOWER POTENTIAL

One of the renewable energy sources is undoubtedly the energy of water, and in fact hydropower (mechanical energy of water in accordance with the Act) [3]. The world theoretical hydropower potential, according to various sources, ranges from approximately 45.7 to 128 PWh / year (petawatt hour = 1015 hours), while the technical potential ranges from 16 to 26 PWh / year [4, 5, 6]. In Poland, these resources are estimated in terms of the theoretical potential at 23 TWh / year, and in terms of technical potential at 12 TWh / year [7, 8, 9]. Hydropower supplies approximately 6.5–7% of global energy consumption (approximately 1.9–2% in Poland) [10]. Interestingly, a report by the International

Energy Agency (IEA) Net Zero by 2050 [11], published in May 2021, suggests that the world will need 2,600 GW of hydropower capacity by the middle of the century to be able to sustain global temperature rise below 1.5 degrees Celsius.

ENERGY POTENTIAL IN MUNICIPAL AND INDUSTRIAL INSTALLATIONS

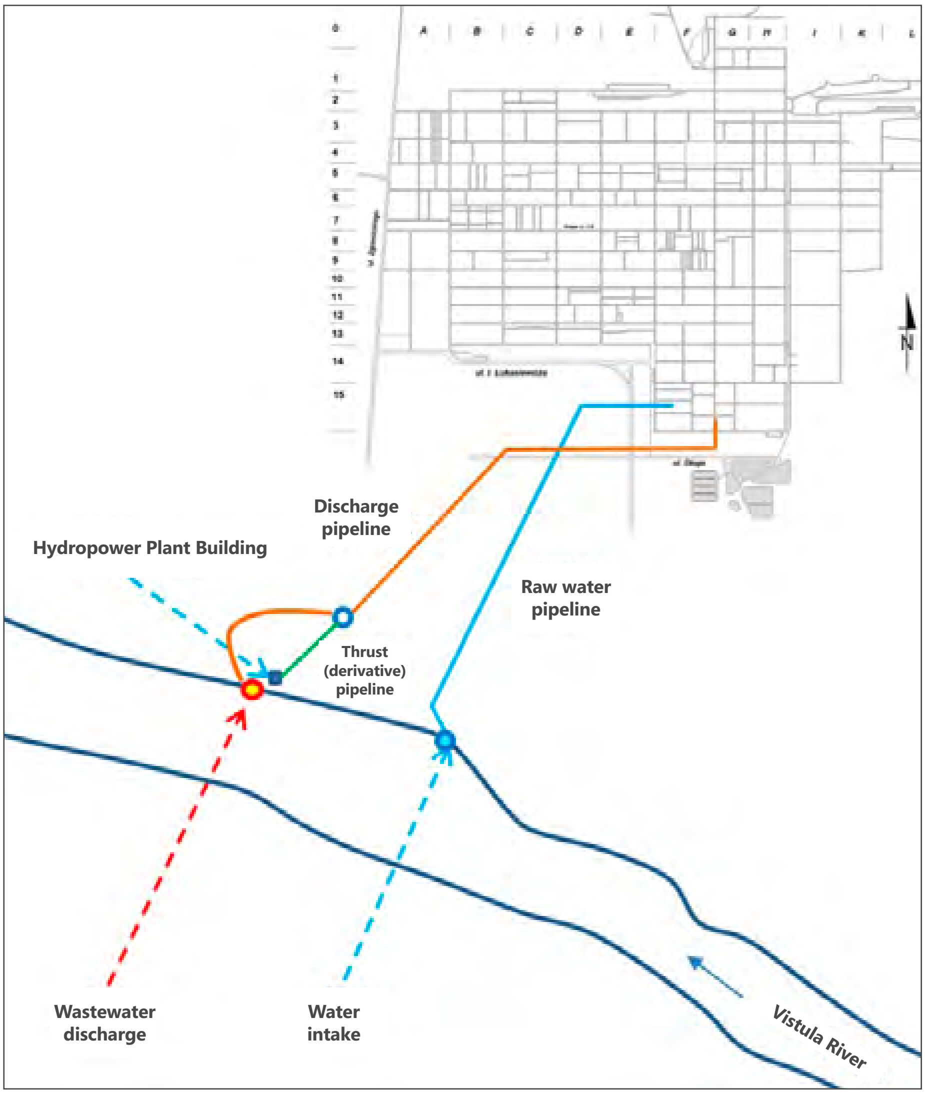
The combination of resources such as water and energy becomes one of the key determinants of ensuring the conditions for sustainable civilization development, both globally and locally. These goods are necessary not only for global production, but also for living processes. Hence, water and wastewater management is – apart from air protection – one of the components of the environment and an important area when it comes to an integrated approach to managing environmental issues.

Both in the urban and industrial infrastructure there are facilities such as water supply systems or wastewater treatment plants, in which some of the energy necessary to ensure the proper operation of the installation is dissipated, e.g. through the discharge of water purified from wastewater treatment plants or in devices used to reduce pressure in water-supply system. Recovering the energy that has been irretrievably lost, while maintaining the efficiency of the installation, is the essence of the technology by which we obtain the so-called clean energy. Devices used to recover lost energy (e.g. water turbines) do not emit greenhouse gases and other pollutants into the atmosphere during the production process. Their installation in the existing infrastructure (synergy) thus limits the scope of construction works. Moreover, such a solution does not require the construction of damming devices (a diversion dam) or flooding the area with the reservoir. It is also a solution that reduces greenhouse gas emissions and contributes to the infrastructure energy security.

There are examples of hydropower plants operating in wastewater treatment plants in the world energy industry. This proves that there is interest in such solutions, but still lacking awareness of their potential (The World Small Hydropower Development Report 2019), despite the fact that water and wastewater management uses about 30% of the energy requirements of companies, and cities – 25 to 40% of energy for water and sewage management requirements [2]. For example, the Swiss calculated that their country's wastewater treatment system consumes 3–5% of the country's energy requirements, which translates to 0.6 TWh per year. On the other hand, in the USA, the wastewater treatment sector amounts to 15 TWh per year [12]. Reducing the electricity consumption of water and wastewater systems in cities and manufacturing plants is becoming a challenge. Energy recovery through local hydropower can be a way to deal with high electricity expenditure in wastewater systems. In line with the new wastewater treatment paradigm, wastewater treatment plants should be designed with a view to maximizing resource and energy recovery. This is due to the fact that the environmental footprint, product and organization carbon footprint, and water footprint remain important issues in environmental management. This new approach highlights the shift towards energy neutral or even energy positive objects.

Appropriate innovative management processes in this area will ensure, in addition to reducing the amount of water abstracted and wastewater discharged, also minimizing the impact on the environment, improving efficiency and energy indicators and the organisation's product benchmarks, supporting the building of a competitive advantage. Therefore, in the pursuit of sustainable development in wastewater treatment, a comprehensive and multi-criteria approach is necessary, as well as extending the boundaries of the system beyond the wastewater treatment plant. Increasing the share of renewable energy in off-site electricity production can also support wastewater treatment plant activities. When it comes to energy neutrality in wastewater treatment plants, it is crucial to use all possibilities to cover the energy consumption necessary for the conducted processes. Then one can talk about emission neutrality, applying technological solutions enabling its achievement and taking into account the technical and economic implications.

Fig. Location of the Płock Hydroelectric Power Plant.



Source: PKN ORLEN S.A.

ENERGY RECOVERY ON THE EXAMPLE OF AN INDUSTRIAL WASTEWATER TREATMENT PLANT IN PŁOCK

Water and wastewater management in PKN ORLEN, the largest company in the fuel and energy industry in Central and Eastern Europe, consists of two installation units, which include: the Water Production Department and the Central Sewage Treatment Plant (CWTP). CWTP is one of the most effective, comprehensive industrial treatment plants. Its task is to treat wastewater as well as rainwater and drainage water from production installations located in the refinery, petrochemical and energy complex (multi utility) in Płock. Waste water, in the form of social and industrial sewage, generated in technological processes on production installations, as well as rainfall and drainage water from the Production Plant in Płock, are discharged to the surface waters of the Vistula River.

On an annual average, according to data for 2018 (taking into account the integrated CCGT (Combined Cycle Gas Turbine) block), about 15.5 million m³ of sewage flows into the CWTP, of which approximately 8 million m³ is industrial sewage from I and II industrial sewage systems. The rest are rainfall and drainage waters from the Refinery Rainfall Sewage System and the Petrochemical Rainfall Sewage System. This sewage is directed to the river through a pipeline with a diameter of 1400 mm. Due to the elevation of the terrain and the location of the production complex over 60 m above the river level, it creates good conditions for the use of the hydropower potential of the treated wastewater discharged from the CWTP to the Vistula.

PKN ORLEN used this potential in 1995, putting into operation a hydro unit equipped with a horizontal Francis turbine (158 kW, CKD Blansko), coupled (elastic coupling) with an asynchronous generator (CELMA engine). The water is supplied to the turbine through a DN600, PN16 thrust (derivative) pipeline with a length of 280 m, which is an outlet from the main pipeline. Due to the operating characteristics of the refinery, there is an uninterrupted discharge of sewage, enabling the continuous operation of the hydropower plant. The occurring breaks in production are dictated by the implementation of periodic service activities. All equipment and technological installations are located in the power plant building with a usable area of 46 m². The operation of the hydroelectric plant at the Płock Hydroelectric Power Plant, which lasted from the mid-nineties of the last century to 2016, proved the legitimacy of using the hydropower potential of treated wastewater from the industrial wastewater treatment plant located on the industrial premises of PKN ORLEN, discharged to the Vistula River (Włocławski Lagoon), for the production of electricity. Over 25 years of experience in the use of a hydroelectric power plant has indicated many of its advantages, but also challenges in terms of infrastructure and the selection of technical parameters of the hydroelectric power plant.

MODERNIZATION IS A WAY TO IMPROVE EFFICIENCY

Taking into account environmental considerations, challenges related to energy efficiency and energy recovery, improving the efficiency of this area as an added value for the company, PKN ORLEN decided to modernize the hydroelectric power plant. In order to develop the most technically and economically advantageous variant of modernization, PKN ORLEN joined, as a cooperating partner, the LIFE Nexus project, which under measure B 3.1 promotes the recovery of energy lost in reducing nodes of drinking water and water discharged into watercourses previously used in installations technological industrial plants, as well as treated wastewater discharged from wastewater treatment plants.

Joining the LIFE Nexus project has opened up opportunities to benefit from the experience of other countries in this field. As part of the project of the European Commission LIFE Nexus, in accordance with the signed contracts coordinated by the CARTIF Technology Center based in Valladolid, Spain, a study prepared in cooperation with the Institute of Fluid-Flow Machinery of R. Szewalski of the Polish Academy of Sciences was obtained. The study: "Preliminary feasibility study for the works necessary to resume hydraulic energy recovery at the discharge of water from the sewage treatment plant of the PKN ORLEN crude oil refinery" includes an analysis of the available hydropower potential; inventory of the hydraulic system; general multi-variant concept of the installation modernization; estimation of the annual electricity production; an estimate of the investment costs and an economic analysis including NPV and payback time calculations assuming prevailing electricity prices.

The aforementioned study allowed for the development of technically and economically viable options for the modernization of the hydroelectric power plant, together with the recommendation of the most advantageous option from the point of view of optimizing the use of the hydropower potential at its disposal. Currently, a tender procedure is underway for a comprehensive modernization of the installation, which will be implemented in the "design and build" formula. Completion of the project is scheduled for 2023.

Arkadiusz Kamiński, BEng, PhD, DSc
Area of the Member of the Management Board for Operations PKN ORLEN S.A.

Bibliography:

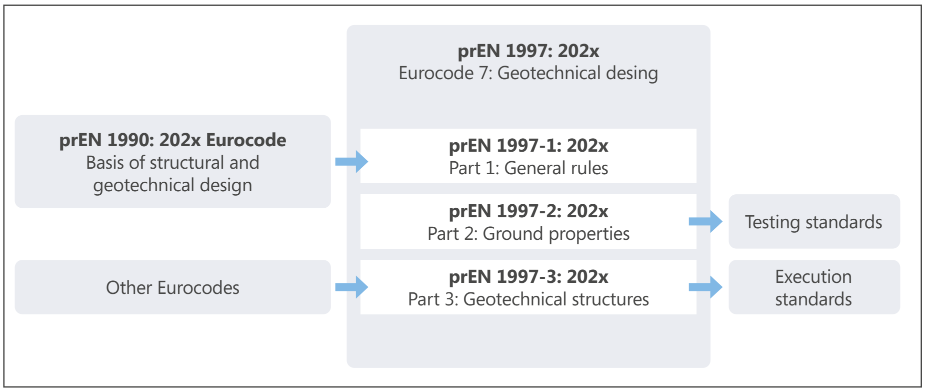
1. Kamiński A., Garstka J., Mościbroda P.: Efektywność energetyczna elementem zintegrowanego zarządzania w ochronie środowiska. Konferencja Naukowo-Techniczna Innowacje w Przemyśle Chemicznym, Rzeszów, 13–14.11.2018; Monografia Polskiej Izby Przemysłu Chemicznego ISBN 978-83-916361-3-8.
2. Kamiński A., Koziczyński P.: Innowacyjne rozwiązania i technologie w gospodarce wodno-ściekowej będącej elementem zintegrowanego zarządzania w ochronie środowiska. Konferencja Naukowo-Techniczna Innowacje w Przemyśle Chemicznym, Rzeszów, 13–14.11.2018 r. Monografia Polskiej Izby Przemysłu Chemicznego ISBN 978-83-916361-3-8.
3. Ustawa z dnia 20 lutego 2015 r. o odnawialnych źródłach energii. (T.J. Dz U.2021 poz. 610).
4. Zhou Y., Hejazi M., Smith S., Edmonds J., Li H., Clarke L., Calvin K., Thomson A.: A comprehensive view of global potential for hydro-generated electricity. Energy and Environmental Science, Issue 9, 2015.
5. Hoes O.A.C., Meijer L. J. J, van der Ent R. J., van de Giesen N. C.: Systematic high-resolution assessment of global hydropower potential. Published: February 8, 2017, https://doi.org/10.1371/journal.pone.0171844.
6. Edenhofer O. i in., Renewable Energy Sources and Climate Change Mitigation. Special Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, New York 2012.
7. Hoffmann A., Hoffmann M.: Kataster technicznych zasobów sił wodnych w Polsce. 1961.
8. ESHA.: Jak zbudować małą elektrownię wodną? Przewodnik inwestora. 2010.
9. Steller J. Energetyka wodna w Polsce i Unii Europejskiej. Szanse i bariery rozwoju. Krajowe Forum Odnawialnych Źródeł Energii, Warszawa 2005.
10. https://www.iea.org/fuels-and-technologies/hydropower.
11. IEA.: Net zero by 2050. A Roadmap for the Global Energy Sector. May 2021. https://www.iea.org/reports/net-zero-by-2050.
12. Bousquet C., Samora I., Manso P., Rossi L., Heller P., Schleiss A. J.: Assessment of hydropower potential in wastewater systems and application to Switzerland. Renewable Energy, Vol 113, December 2017. https://doi.org/10.1016/j.renene.2017.05.062.

DESIGNING HYDROTECHNICAL STRUCTURES IN THE CONTEXT OF UPCOMING EUROCODES CHANGES – PROLOGUE

The development of the second generation of European standards (Eurocodes) is almost at its end, with formal vote on their final acceptance and introduction planned for 2024, and the implementation by CEN member states required by September 2027. The updated Eurocodes will bring an evolution, not a revolution, when compared to the current design practice. However, some of the introduced changes will be relevant in the context of design of dams and flood protection systems, especially, those composed of soils and fills as main materials. The paper presents the most relevant aspects of the new codes related to the basis of design (prEN 1990 [1]) and geotechnical design (prEN 1997 [2–4]).

The first generation of European standards for structural design was developed over many years, with each new Eurocode or their separate parts added at different times, often with limited coordination of standardization works. This resulted in some inconsistencies within the code as well as relative difficulty of use, comparing to previous national practices and standards used in some countries. The solution for that was found in plans of coordinated revision of all the Eurocodes; the works on their second generation are progressing since 2015. The main aim is to improve the existing codes, update them to the current state-of-the-art level, as well as to increase their ease-of-use in everyday design. All the Eurocodes should be available at similar time as they are developed in parallel. A detailed schedule of introduction of the new Eurocodes has been summarized by Zobel [5]. In the context of design of earth dams and flood protection systems, geotechnical analysis usually plays the most important role; therefore, the main focus of this article is on general rules related to the basis of design (EN 1990) as well as some aspects of geotechnical design (EN 1997). The interrelation of specific standard types used in design of geotechnical structures is presented in Fig. 1, in relation to the three parts of the new Eurocode 7 [2–4]. Presented document structure makes the design workflow quite intuitive, but at the same time, it requires a broad knowledge of a number of documents relevant for a particular type of structure. However, as EN 1990 was often ignored by practitioners, as offering only the theoretical basis for other Eurocodes, now its role will increase.

Fig. 1. Relations of new design standards for design of earth structures [7].



prEN 1990: 202x Eurocode: Basis of structural and geotechnical design

The second generation of the EN 1990 standard [1] acknowledges the importance of geotechnical design as being of equal importance as the design of structural elements composed of produced materials. However, the major changes introduced in this standard are of general nature. One of them is the increased importance of consequence classes and the way in which they will affect the design. Five consequence classes CC0 – CC4 (Tab. 1) were distinguished instead of three specified previously. Their choice is still based on the potential consequences to human life as well as other potential impacts (e.g. social, environmental).

The Eurocodes are intended for the use in design of structures assigned to classes from CC1 to CC3. It is considered that for very simple, low-risk structures (CC0), the use of such comprehensive standards would be unnecessarily difficult, while for structures associated with extreme potential consequences (CC4 – e.g. large dams, nuclear power plants), Eurocodes alone would be insufficient to provide sufficient reliability and additional guidance is needed. The choice of appropriate consequence class is highly relevant; it has an impact on reliability differentiation introduced in the partial factoring approach in a form of a consequence factor KF (Tab. 2), used to modify default values of partial factors specified for CC2 structures. This finally aligns the design approach of the Eurocodes with the approaches used for flood protection systems in some countries (e.g. Poland), where depending on the risk profile, different levels of safety are expected.

What is also important for hydrotechnical structures is the change in factoring of water pressures (Tab. 2). The values of partial factors for actions resulting from water pressures will differ from those used for actions with other sources.

prEN 1997-1: 202x Eurocode 7: Geotechnical design – Part 1 : General rules

The first noticeable change in geotechnical design standard is related to the structure of the new version of the code (Tab. 3). Instead of two parts, previously, the code is separated into three, covering general aspects of design, ground properties, and design requirements for specific structure types, respectively.

Part one of the code provides additional guidance on general design aspects, which are relevant to geotechnical structures, e.g. Geotechnical Categories (Tab. 4). The use of Geotechnical Categories (GC) in the current version of the standard was limited, as not all of the countries fully adopted them in their national practices; moreover, the relation of the GC to specific requirements of the code was not sufficiently strong. In the second generation of the Eurocode 7, GC will be selected based on the Conse-

Tab. 1. Qualification of consequence classes [1].

Consequence class	Indicative qualification of consequences	
	Loss of human life or personal injury	Economic, social or environmental consequences
CC4 – Highest	Extreme	Huge
CC3 – Higher	High	Very great
CC2 – Normal	Medium	Considerable
CC1 – Lower	Low	Small
CC0 – Lowest	Very low	Insignificant

Tab. 2. Partial factors on actions and effects for fundamental (persistent and transient) design situations in the case of buildings.

Action or effect				Partial factors γ_F and γ_E for Design Cases 1 to 4				
Type	Group	Symbol	Resulting effect	Structural resistance	Static equilibrium and uplift		Geotechnical design	
				DC1	DC2(a)	DC2(b)	DC3	DC4
Permanent action G_k	All (except water)	γ_G	unfavourable /destabilizing	1.35 K_F	1.35 K_F	1.00	1.00	not used
	Water	$\gamma_{G,w}$		1.20 K_F	1.20 K_F			
	All (except water)	$\gamma_{G,stb}$	stabilizing	not used	1.15		not used	
	Water	$\gamma_{G,w,stb}$			1.00			
	All	$\gamma_{G,fav}$	favourable	1.00	1.00		1.00	
Variable action Q_k	All (except water)	γ_Q	unfavourable	1.50 K_F	1.50 K_F		1.30	1.10 (γ_Q / γ_G)
	Water	$\gamma_{Q,w}$		1.35 K_F	1.35 K_F		1.15	1.00
	All	$\gamma_{Q,fav}$	favourable	0				
Effects of actions **E**		γ_E	unfavourable	effects are not factored				1.35 K_F
		$\gamma_{E,fav}$	favourable					1.00

Tab. 3. General content of prEN 1997 [2–4].

Chapter	Part 1: General rules	Part 2: Ground properties	Part 3: Geotechnical structures
–	Introduction	Introduction	Introduction
1	Scope	Scope	Scope
2	Normative references	Normative references	Normative references
3	Terms, definitions and symbols	Terms, definitions and symbols	Terms, definitions and symbols
4	Basis of design	Ground model	Slopes, cuttings, and embankments
5	Materials	Ground investigation	Spread foundations
6	Groundwater	Description and classification of the ground	Piled foundations
7	Geotechnical analysis	State, physical, and chemical properties	Retaining structures
8	Ultimate limit states	Strength	Anchors
9	Serviceability limit states	Stiffness, compressibility and consolidation	Reinforced fill structures
10	Implementation of design	Cyclic, dynamic, and seismic properties	Ground reinforcing elements
11	Testing	Groundwater and geohydraulic properties	Ground improvement
12	Reporting	Geothermal properties	Groundwater control
13	–	Reporting	–

Tab. 4. Selection of Geotechnical Category [2].

Consequence Class	Geotechnical Complexity Class		
	Lower (GCC1)	Normal (GCC2)	Higher (GCC3)
Higher (CC3)	GC2	GC3	GC3
Normal (CC2)	GC2	GC2	GC3
Lower (CC1)	GC1	GC2	GC2

quence Class qualification and in relation to the ground conditions expressed through Geotechnical Complexity Class (GCC). The choice of the Geotechnical Category will affect various aspects of design and execution process (Fig. 2), setting the minimum required levels of ground investigation, supervision, verification, monitoring, etc. Such approach is in line with current state-of-the-art practice and mostly aims to formalize the requirements to follow those best practices. For structures characterized by a higher risk profile (GC3); extended independent design verification and supervision of construction will be recommended, preferably by an independent third party (e.g. geotechnical consultant). Extended quality control aims to ensure that the specified higher reliability level can in fact be achieved and to eliminate any potential human errors at all stages of the project.

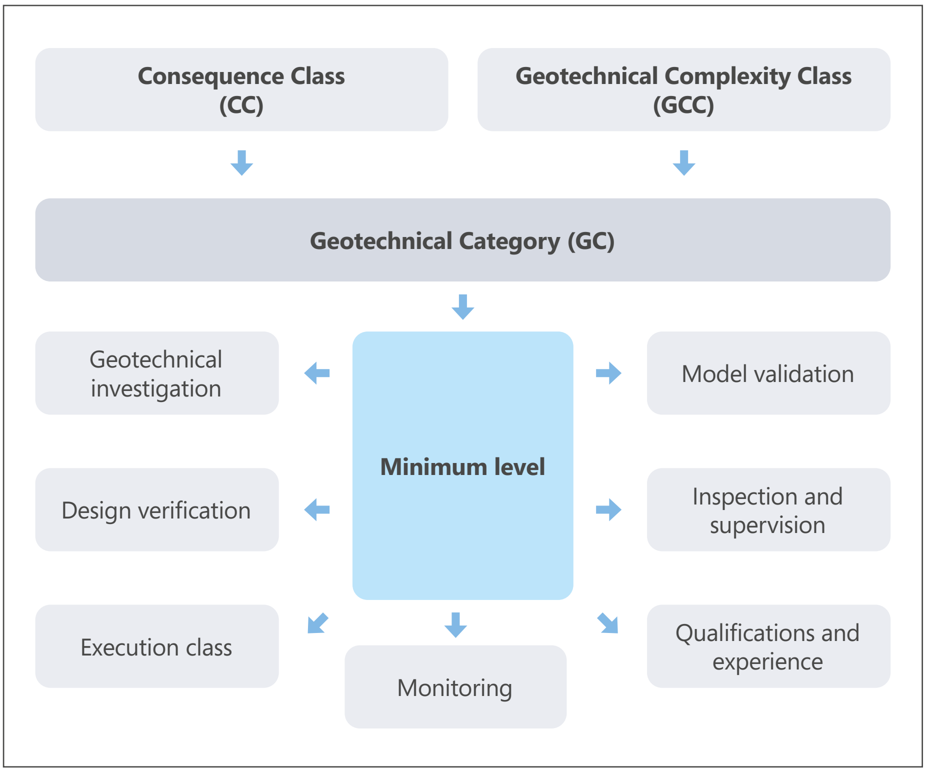
Part one of EN 1997 will also cover the choice of representative values of actions associated with water levels, which will be based primarily on statistical data and probabilities of occurrence. Such approach is already common in design of hydrotechnical structures as it provides the most rational basis when water pressures are dominant actions.

prEN 1997-2: 202x Eurocode 7: Geotechnical design – Part 2 : Ground properties

Part two of the new version of the code will change from description of testing methods to providing requirements and recommendations relate to ground properties. The aim is to focus on the needs of designers instead of the needs of people responsible for geotechnical documentation and testing.

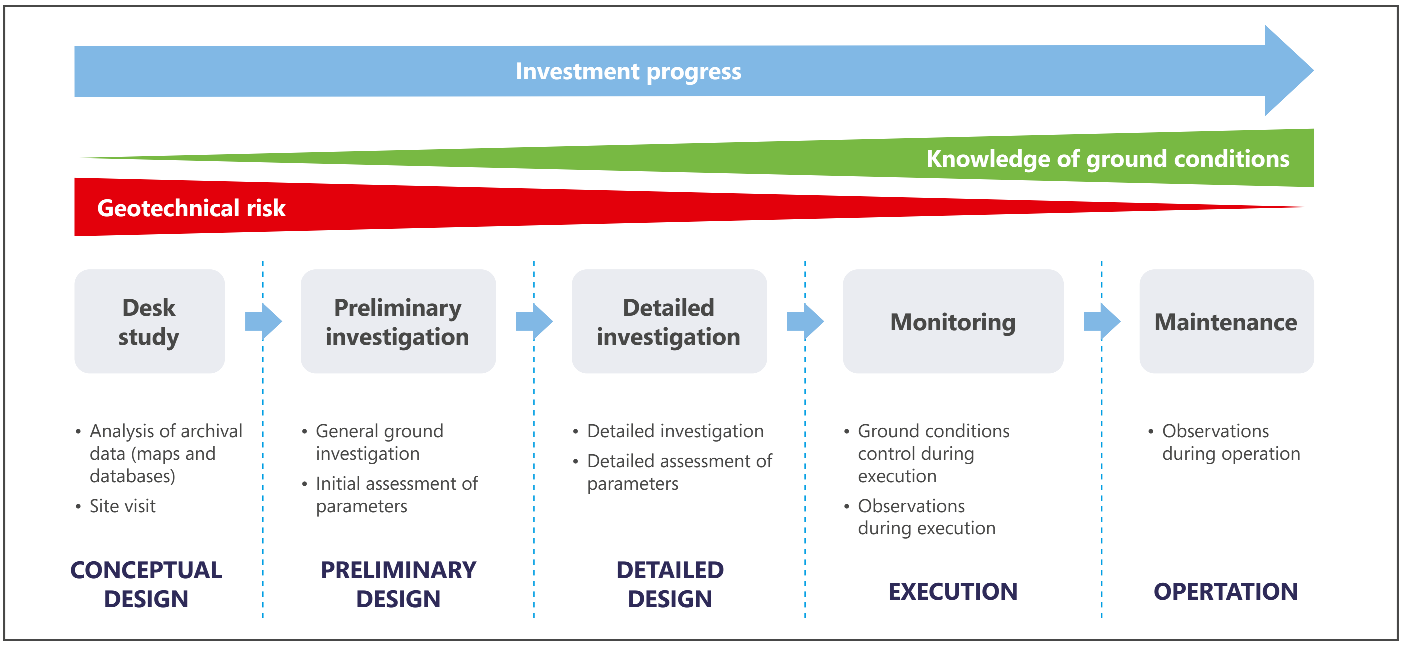
Ground investigation is a continuous process (Fig. 3). For large projects, it can be divided into five separate stages, related to the progress of the investment. It should start with desk study, when available archival data, publicly accessible databases, and comparable experience are used to make first assumptions about ground conditions and their complexity. Based on those initial assumptions, preliminary ground investigation program can be designed. It is often followed by detailed investigation in order to refined the ground model and adjust the location of investigation points to the final location of the designed structure. Monitoring stage during the construction should serve as validation of design assumptions (i.e. comparison of assumed ground model and real conditions). It may also involve additional tests that should be documented in the form of geotechnical reports, which should become a part of as-built documentation. In some cases, additional knowledge about geotechnical conditions can be gained during the operation of the structure at the maintenance stage; it may involve additional tests as well as observations (e.g. settlements). With the progress of the investment, as the knowledge of ground conditions increases, the uncertainty and geotechnical risk.

Fig. 2. Relation of quality management aspects to geotechnical category of a structure.



This part of the code has been supplemented with state-of-the-art recommendations related to non-linear behavior of soils as well as parameters relevant for cyclic and dynamic loads. New additions also include thermal properties and more guidance related to permeability of the ground. From the point of view of design of hydrotechnical structures, the latter addition is the most relevant, as current version of the code offered little information on those aspects of the ground. Especially, in the case of hydrotechnical structures, the range of groundwater investigation, which is one of the most important issues in geotechnical design, has been clarified. According to [3], groundwater investigations should provide more detail information based on in situ and laboratory tests (Tab. 5). In addition to mechanical properties, in the analysis of ultimate limit states associated with hydraulic failures, it is important to consider hydraulic properties as well. In their cause, it is also important to account for the accuracy of the method [9]. On the example of coefficient of permeability, different methods characterized by different level of reliability of estimation can be distinguished (Tab. 6). The least accurate methods (with highest uncertainty) are those based on empirical relations – type C. The extent of their applicability should be always verified in the context of their limitations (e.g. soil type, local aspect of the correlation). Higher level of reliability can be obtained based on indirect measurements (type B), where the accuracy is dependent on assumed simplifications in description of the phenomenon, and the results are obtained on the basis of observed indirect quantities (flow rate or pore pressure). The highest level of reliability of parameter assumption is possible based on direct measurements – type A. To obtain those values, a range of laboratory methods can be used. Their advantage lies in the possibility of modeling the flow with consideration of the character, direction and rate (gradient) of the flow with full definition of boundary conditions (control of test conditions). The disadvantage is associated with the results being limited to the sample itself. Representa-

Fig. 3. Stages of ground investigation in relation to the investment progress [5].



tiveness of the sample, in terms of relation to real conditions, and scale effects are the simplifications that can affect the interpretation. The direct in situ methods, which allow for assessment of conditions similar to real scale, do not have this disadvantage.

Another issue in the process of choosing a reliable value of the parameter is the method of interpretation [9] and the uncertainty associated with different levels of validation. Four classes of precision, in terms of the phenomenon description, constitutive models, range of empirical data, can be distinguished [11]:

- Class 1 – Rigorous analytical methods;
- Class 2 – Numerical solutions (close approximation);
- Class 3 – Approximate analytical solutions;
- Class 4 – Empirical approaches.

Currently, most methods of interpretation for geotechnical properties are limited to class 4; therefore, the assessment of their usability must be conducted in the context of the validation data (number of real-scale measurements, quantity and quality of laboratory tests, local character of the conditions). This approach and critical analysis of the available correlations allow for the use of parameters for design purposes. For achieving sufficient reliability level of design predictions, the analysis has to be based on parameters that are sufficiently representative for a considered limit state and design situation. For this purpose, it is required that the designer will select a representative (characteristic) value of

Tab. 5. Scope of necessary information for groundwater and hydraulic conductivity [3].

In situ research	Laboratory tests	
• the depth, thickness, extent and conductivity of water-bearing strata in the ground; • joint systems in the rock; • the permeability or hydraulic conductivity of each geotechnical unit; • the piezometric head of aquifers and their variation over time; • actual piezometric heads including possible extreme levels and their periods of recurrence; • the piezometric pressure distribution; • the chemical composition and temperature of groundwater.	*In fine and organic soil:*	• the stress conditions under which the specimen is to be tested; • the criterion for achieving and maintaining the steady-state flow condition; • the direction of flow through the specimen; • the hydraulic gradient under which the specimen is to be tested; • the need for back-pressure and the required degree of saturation; • the chemistry of percolating water;
	In coarse soil:	• the density index to which the specimen is to be prepared; • the hydraulic gradient under which the specimen is to be tested; • the need for back-pressure and the required degree of saturation

Tab. 6. Accuracy of methods for determining geotechnical parameters on the example of coefficient of hydraulic conductivity (adapted from [3]).

Methods	Direct evaluation – type A	Indirect evaluation – type B	Empirical rules – type C
Laboratory tests	Constant and falling head tests (EN ISO 17892-11)	Derivation from compressibility test (for example: oedometer test) for cohesive soils.	Derivation of empirical hydraulic conductivity can be based upon grain size distribution and relative density or porosity for coarse and very coarse soil (like: Hazen formula, USBSC formula, Seelheim formula, etc) [10].
In situ tests	Water permeability test in borehole using: • open system (EN ISO 22282-2) • closed system (EN ISO 22282-6)	Pumping tests (EN ISO 22282-4)	Derivation of empirical hydraulic conductivity can be based on formulas from in situ test, related to the dispersion of pore pressure or compressibility index (like: DMT, PMT) [11].
	Water pressure tests in rock (EN ISO 22282-3)	Dissipation test DPT (EN ISO 22476-1) - most often during static piezocone test (CPTU) or BAT	
	Infiltrometer tests: • ring infiltrometer tests (EN ISO 22282-5) • Lugeon type test (ASTM D4630-96)		

Fig. 4. The choice of parameters in geotechnical design [7].

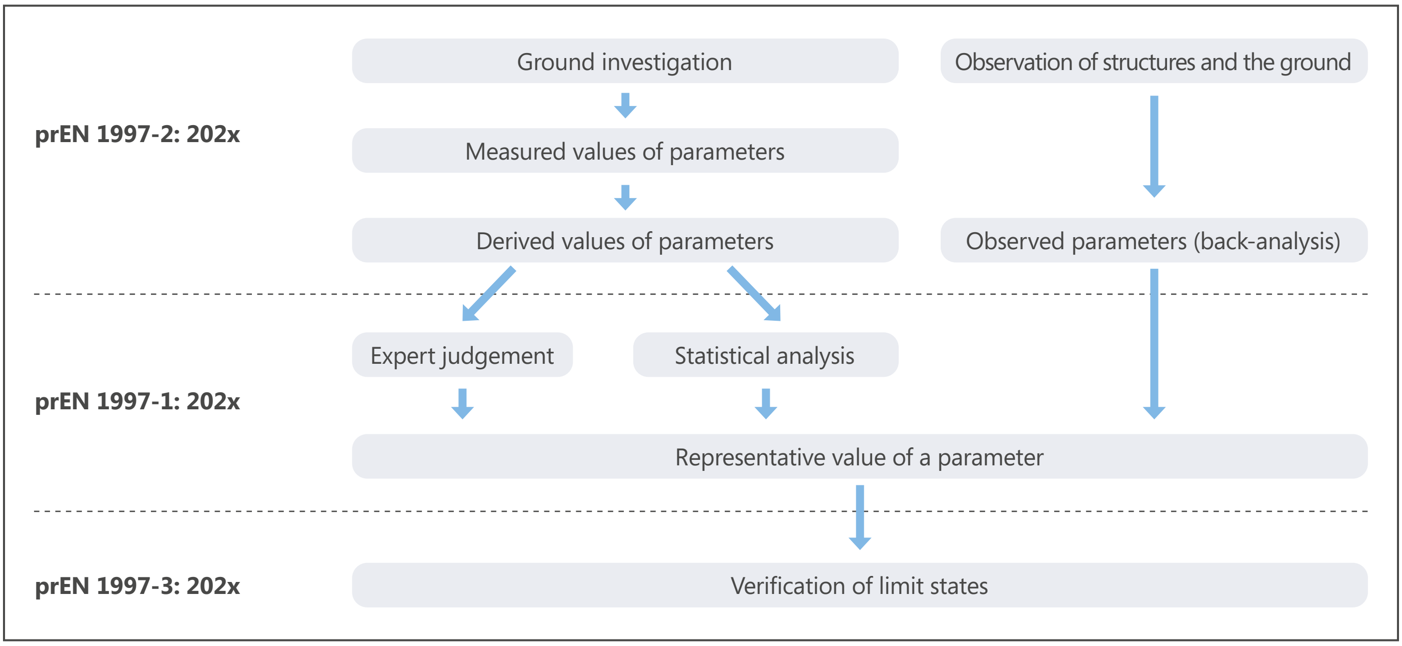
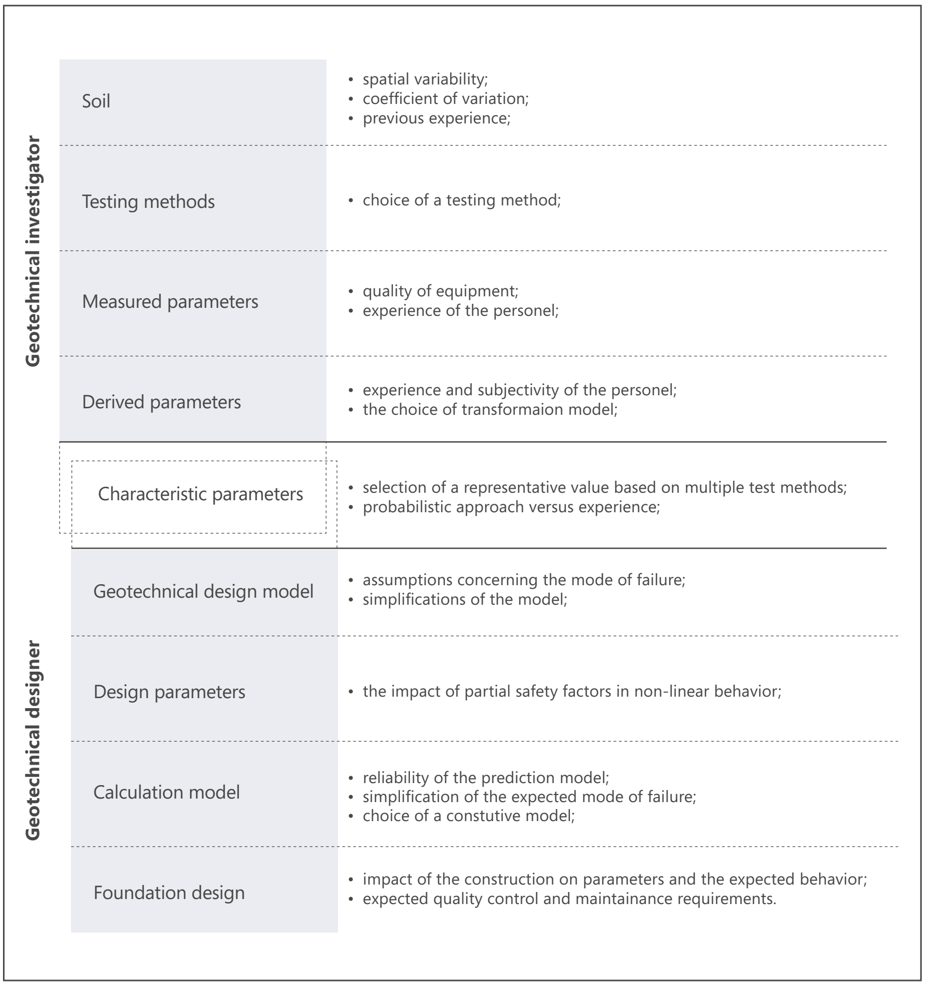


Fig. 5. Sheme for determining the representative value of a soil parameter in the geotechnical design process [9].



a ground parameter based on documented ground conditions and selected geotechnical investigation methodology (fig. 5) Those parameters can be chosen in design using three possible ways (5). Two of them are based on parameters derived from values measured from ground investigation. Based on the test results, it is possible to use either expert judgment (e.g. involving comparable experience) or statistical analysis. Alternatively, parameters can be estimated based on observations of other structures or the ground behavior through back-analysis of relevant parameters (e.g. strength parameters back-analyzed from observed landslides, deformation modulus estimated based on observed settlements). The chosen representative value of a given parameter can be used for verification of relevant limit states in design.

prEN 1997-3: 202x Eurocode 7: Geotechnical design – Part 3: Geotechnical structures

Part 3 of the second generation Eurocode 7 is a completely new addition to the code. Its main aim is to provide more detailed guidance related to specific geotechnical structures. Each of the structures is covered by a separate chapter (Tab. 3) and an additional informative annex. Elements excluded from the current part 1 (e.g. spread foundations, piles, etc.) have been updated to reflect the current state of knowledge and state-of-the-art of the industry. In addition to that, new chapters have been added on ground and fill reinforcement (e.g. with geosynthetics), ground improvement (e.g. stone columns, rigid inclusions, soil mixing), and groundwater control (e.g. drainage, cut-off walls, impermeable barriers).

SUMMARY AND CONCLUSIONS

The introduction of the second generation Eurocodes is still few years away, but main drafting works have already been finalized. Before the official implementation of the new version of the Eurocodes, it is beneficial for designers to comprehend the main ideas behind the introduced changes. The new Eurocodes will reflect current state of the art in design, increasingly based on the concept of reliability through semi-probabilistic application of partial factors of safety and leaving behind the global safety factors used in many countries beforehand. This approach has been based on more rational consideration of uncertainties underlying the geotechnical practice – moving towards widespread use of Reliability Based Design [9]. Although much of the new content will be highly useful for design of earth dams and levees, still additional requirements might be necessary for sufficient specification of design requirement relevant for those structures. For example, the new code still lacks sufficient guidance on allowable values of critical hydraulic gradient for verification of the limit state related to internal erosion [8]. It might be beneficial to develop dedicated guidelines, based on the new requirements, providing designers with guidance specific for design of hydrotechnical structures. Considering the changes introduced in the code, additional guidance would be useful on ground investigation and verification of hydraulic limit states. The Eurocodes will provide only the general framework in those regards.

Witold Bogusz
DSc, PhD, Eng, Leader of CEN TC 250/SC7/TG-D1
"Slopes, Retaining Structures and Anchors"

Tomasz Godlewski
DSc, PhD, Eng,, Assoc. Prof.
Building Structures, Geotechnics and Concrete
Department, Building Research Institute, Poland

Bibliography:

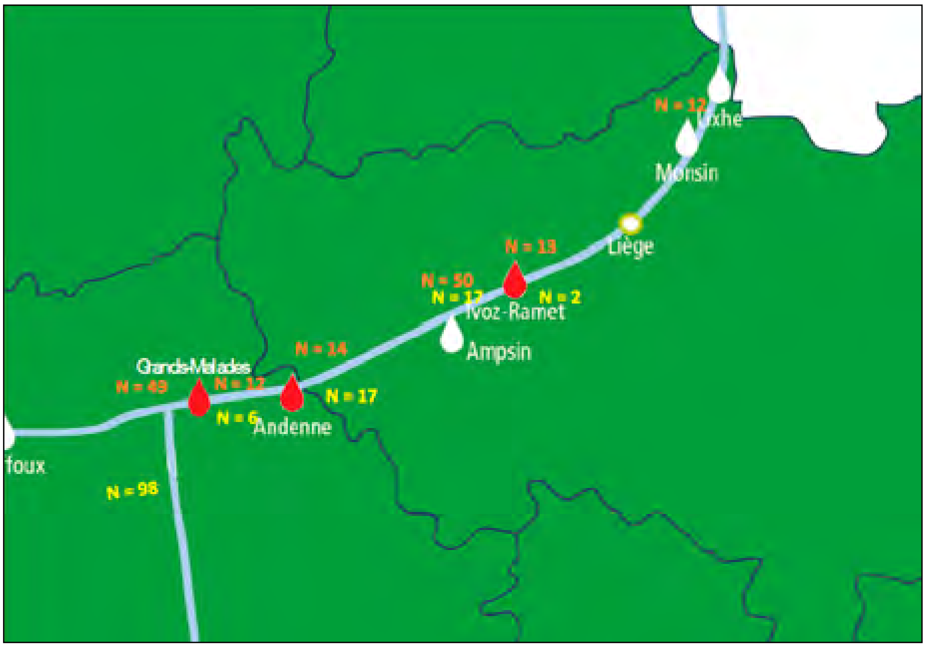
1. prEN 1990: 202x Eurocode: Basis of structural and geotechnical design (draft 09–2020).
2. prEN 1997-1: 202x Eurocode 7: Geotechnical design – part 1: General rules (draft 04–2021).
3. prEN 1997-2: 202x Eurocode 7: Geotechnical design – part 2: Ground properties (draft 04–2021).
4. prEN 1997-3: 202x Eurocode 7: Geotechnical design – part 3: Geotechnical structures (draft 04–2021).
5. Zobel H., Normalizacja w procesie projektowania w budownictwie, Inżynier Budownictwa 1/2021 (in Polish).
6. Bogusz W., Kłosiński B., Projekt EN 1997: 202x Eurokod 7 Projektowanie geotechniczne, Inżynier Budownictwa 2/2021 (in Polish).
7. Bogusz W., Leszczyński M., Nowa generacja Eurokodu 7 – Rola rozpoznania podłoża w projektowaniu geotechnicznym, Geoinżynieria Drogi Mosty Tunele 4/2019 (in Polish).
8. Godlewski T., Bogusz W., Sufozja jako forma zniszczenia hydraulicznego w aktualnym ujęciu wymagań projektowych, Energetyka wodna, 2/2021 (38), str. 46–48. (in Polish)
9. Godlewski T., Bogusz W. – Philosophy of Geotechnical Design in Civil Engineering – Possibilities and Risks, Bulletin of the Polish Academy of Sciences – Technical Sciences, 2019, Vol.67, nr 2, s. 289–306 DOI: 10.24425/bpas.2019.12825, 2019.
10. Jaśkiewicz J., Godlewski T., Verification of determination of hydraulic conductivity for coarse soils by empirical formulas based on the density index, Acta Scientiarum Polonorum, Architektura-Budownictwo, 2021, nr 20 (2), s. 83–92.
11. Schnaid F., In situ testing in geomechanics. Taylor & Francis, London – New York, 2009.

EVALUATION OF THE EFFECTIVENESS OF METHODS MINIMIZING THE LIMITATIONS OF **SILVER EEL MIGRATION**

Hydroelectric power stations are one of the most intensively exploited renewable energy sources. They account for around 17% of the world's total electricity production. Nevertheless, their construction is not neutral to the environment. The most significant negative effect of hydropower construction is river fragmentation, i.e. the disruption of ecological continuity preventing upstream and downstream migration of fish and other organisms. In Europe, silver eels and salmon are the main species affected.

The Life4Fish research project was launched on the Meuse River in 2017 to investigate what mitigation measures can be implemented to protect the silver eel during its migration to the sea. The research was divided into two phases. The first phase was launched in 2017 and involved the release of 150 marked eels in a section of the Meuse River where there are six hydropower stations. Subsequently, the natural flow of the eels to the sea was recorded using a network of antennae. On this basis, a map of the movement routes of silver eels along the surveyed stretch of river was prepared. The second phase of the study was launched in 2019 and involved selecting three solutions to support and protect the eel during migration. Three hydroelectric power stations belonging to Luminus from Belgium were selected as the study sites. For the purpose of assessing the effectiveness of the selected protection measures, 140 marked eels were released in the vicinity of the selected sites.

Fig. 1. Overview of the three sites selected for testing eel protection measures (red). Release sites for marked eels into the Meuse River in 2017 (orange) and 2019 (yellow) (Sonny et al. 2020).



IMPLEMENTED SOLUTIONS

As part of the project and on the basis of a subsequent tendering procedure three solutions were selected.

a) Electrical barrier Neptune – Grands-Malades Hydroelectric Power Station (CHG)

At the inlet to the hydroelectric power station in Grands-Malades an electrical barrier NEPTUN of the Polish company PROCOM SYSTEM S.A. was installed. The barrier consisted of two rows of positive and negative electrodes. The electrodes were made of stainless steel pipes that were installed vertically across the inlet channel to the power station. The vertical position was achieved by mounting the lower part of the electrodes to chains stretched across the river bed and mounting a float at the top.

b) Turbine management and migration model – Andenne Hydroelectric Power Station (CHA)

Within the LIFE4FISH project, a predictive model based on various environmental factors was developed to forecast downstream migration peaks of silver eels. Among the 10 environmental factors that were statistically examined for their influence on the probability of eel migration in the 2017 telemetry data set, only 3 variables demonstrated a relative influence and were used to determine the probability of silver eel migration. The final operational sequence of the prepared model for the Meuse River is:

- a migration period between 20 August and 28 February,
- a flow of the Meuse River over 300 m³/s,
- a discharge gradient of over 35 m³/s in the Meuse River compared to the previous 5 days.

Under the above conditions and the consequent potential migration of eels, it was assumed that the turbines at the Andenne hydroelectric power station would be deactivated between 18.00 and 6.00 in the morning.

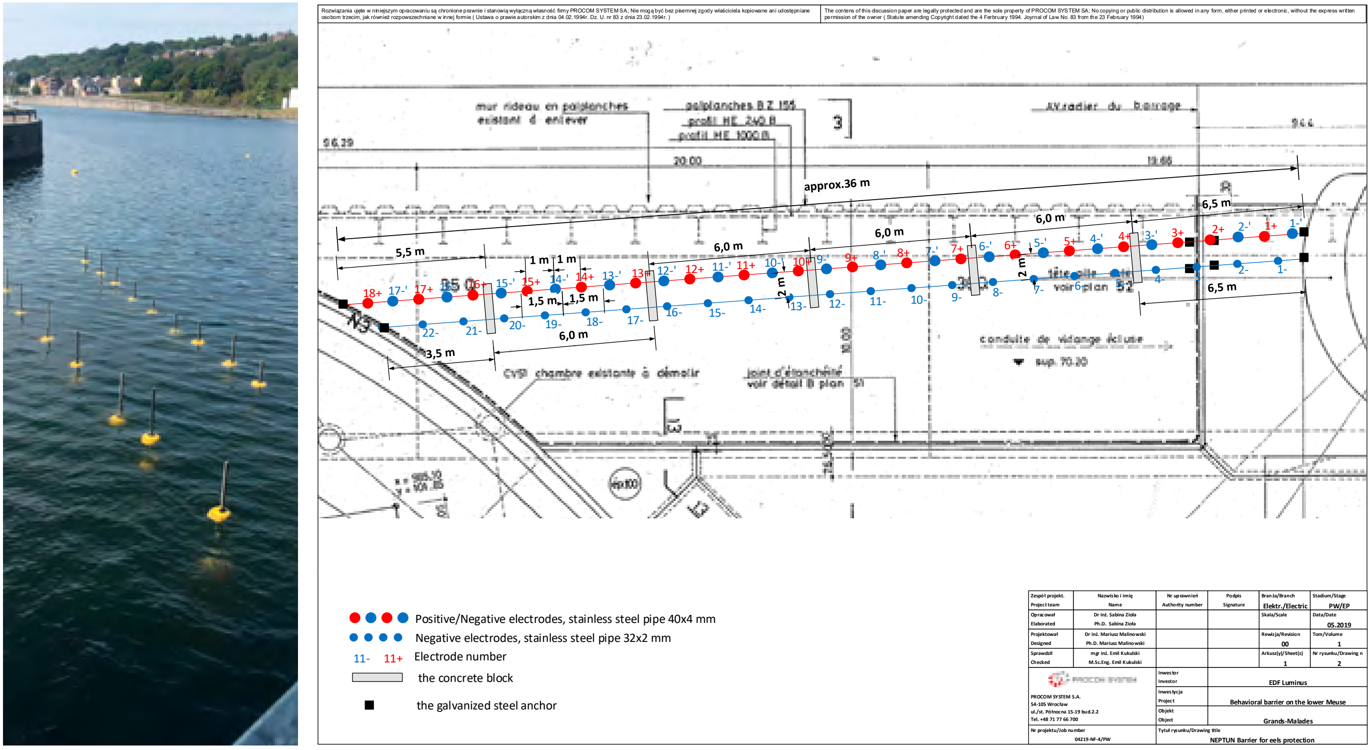
c) Bubble barrier – Hydroelectric Power Station in Ivoz-Ramet (CHR)

A bubble barrier manufactured by Belgian company APUMAS has been installed at the inlet channel of the Ivoz-Ramet hydroelectric power station. The principle of the bubble barrier involves supplying compressed air (200 m³/h) to a pipe with holes, installed on the river bed along the intake of the CHR inlet channel at its junction with the Muse. Pipes were installed 10 m from the water intake to avoid bubbles entering the intake channel before reaching the water surface (Figure 3).

EFFECTIVENESS EVALUATION

The following method was selected to evaluate the effectiveness of the behavioural barriers used:

Fig. 2. Overview of the Neptune barrier installed at CHG (left) and drawing of the installed electrodes (Sonny et al. 2020).



$$S^{barrier} = \frac{N^{barrier\ (out)}}{N^{barrier\ (in)}}$$

Where:

Sbarrier – is the ratio of all fish that have safely passed the dam to all fish recorded by the set of antennas installed at the dam.

Nbarrier (out) – means the number of fish that have successfully passed the dam,

Nbarrier (in) – means all fish that have been detected by the network of antennas installed on the dam.

TELEMETRY NETWORK

JSAT technology (LOTEK WHS 4250 receivers) was used for data collection, which enabled the tracking of silver eels by detecting coded pulsations transmitted by acoustic markers at 416.7 kHz.

At each site where behavioural barriers were installed, a network of antennas was mounted to obtain a two-dimensional map of the fish's position. The two-dimensional map was obtained using UMAP software provided by LOTEK. Figure 6 illustrates the location of the individual antennas for each site.

RESULTS

a) Neptune electric barrier at CH Grands-Malades (CHG)

In autumn 2019, 98 eels marked with acoustic transmitters were released above the Grands-Malades power station. Twelve antennas were installed to record the eels' migration. Antennas 1 to 4 were located directly in front of the barrier, antennas 5 to 9 were placed at the dam piers, and antennas 10 to 12 were fitted at the water intake for the power plant behind the barrier. Only individuals detected by antennas 1 to 4, i.e. those directly affected by the barrier, were included in the analysis. The behaviour of each eel was examined from its first detection by antennas 1 to 4, until its last detection by one of the antennas above the Grands-Malades site (antennas 1 to 12). During the telemetry test, 82 eels were present at the Grands-Malades site. Out of these, 78 eels were detected by antennas 1 to 4. The remaining individuals were not included in the calculation of the barrier effectiveness factor. Based on the recorded signals, the eels were divided into 3 categories:

- 49 individuals were detected at the dam (antennas 5 to 9) – *Nbarrier (out)*
- 18 individuals were detected in the power station inlet channel (antennas 10 to 12) – *Nbarrier* (failure),

Fig. 3. Schematic overview of the bubble barrier installed along the CHR inlet (Ivoz-Ramet) (Sonny et al. 2020).

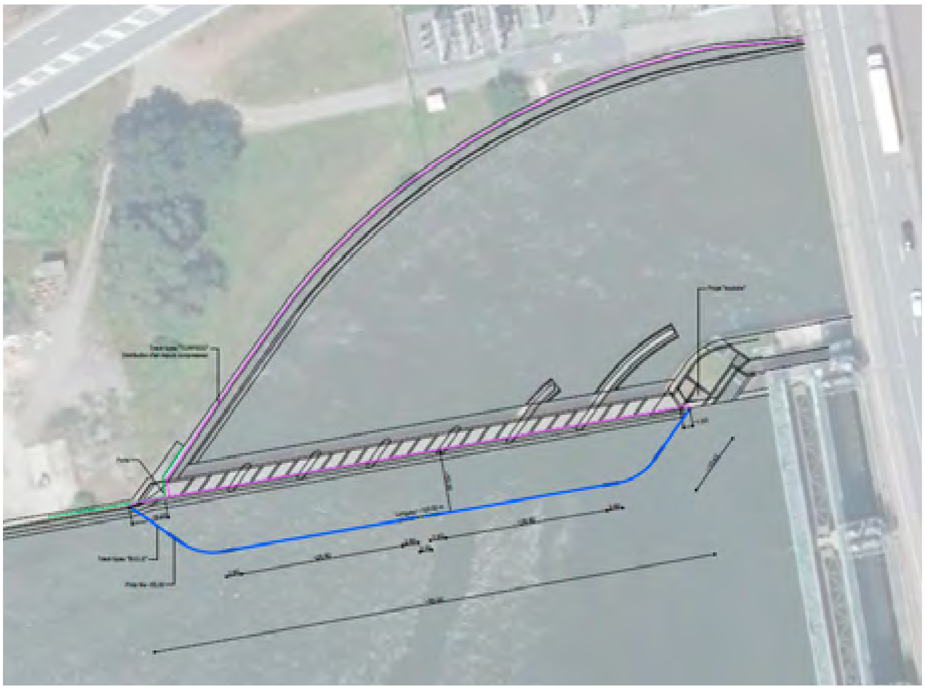
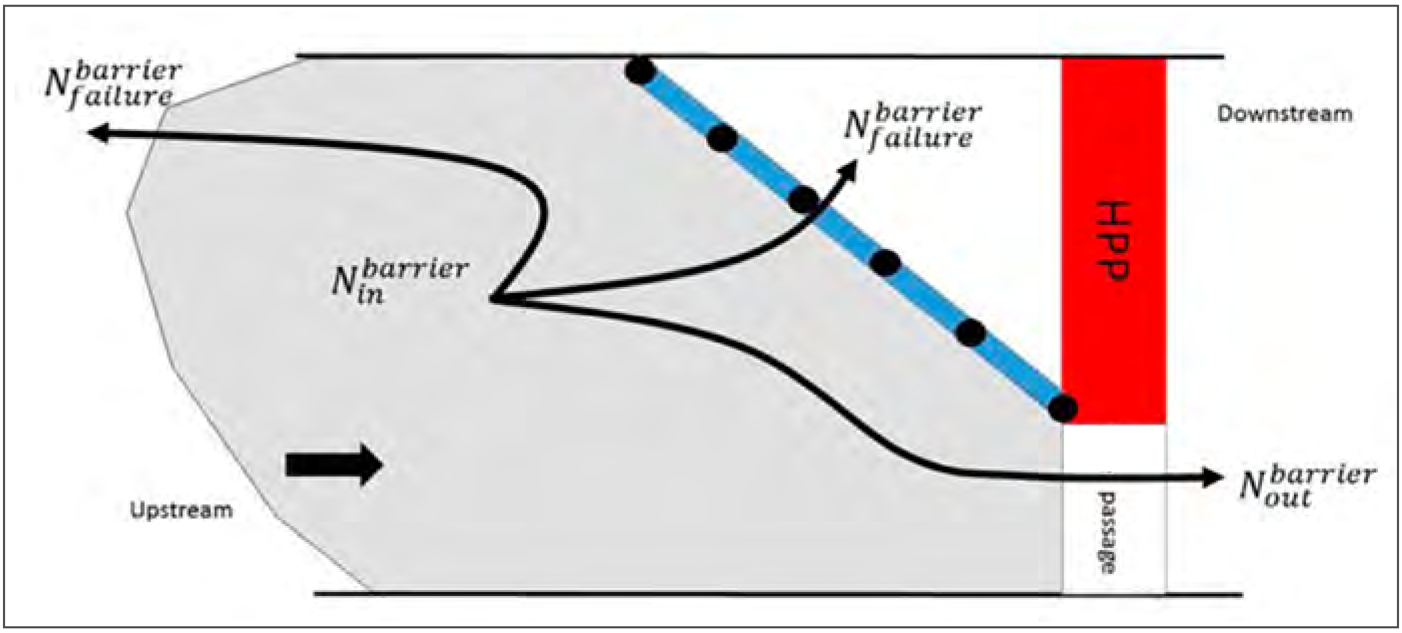


Fig. 4. Measurement of the effectiveness of behavioural barriers (Sonny et al. 2020).



- 2 individuals were detected by antennas 1 to 4 but were not detected at the other antennas – *Nbarrier* (failure)
- 9 individuals after re-analysis of the data were not included as detected by antennae 1 to 4 and were not considered for the barrier effectiveness analysis.

The barrier effectiveness factor was finally calculated as the ratio of the number of individuals that successfully and safely crossed the barrier to the total number of individuals included (sum of the 3 categories defined above).

$$N^{barrier\,(in)} = 69$$
$$N^{barrier\,(out)} = 49$$

Successful migration is

$$S^{barrier} = \frac{N^{barrier\,(out)}}{N^{barrier\,(in)}} = 71\%$$

Nevertheless, considering 2017 data and flows < 300 m³/s in the Meuse River, for which most of the flow is diverted to the power station, the effectiveness of the barrier drops to 52%. This is due to the fact that at higher flows some of the eels run off through the overflows of the dam.

b) Turbine management induced by the eel migration model in Andenne (CHA)

From 20 October 2019 to 29 February 2020, 75 eels crossed the dam throughout the study period, but 11 of these crossed the dam under high hydrological conditions and were not detected by the telemetry network. Furthermore, in order to avoid the influence of the time of release of eels into the river on the time of crossing the dam, 20 eels that crossed the dam within 7 days after their release were excluded from the predictive model performance analysis. According to previous assumptions, the predictive model triggered 32 alarms throughout the study period. Unfortunately, due to communication and coordination problems with the dam operator, only 12 alarms resulted in the successful stoppage of the power plant's turbine during the scheduled hours from 6 pm to 6 am.

Based on the signals recorded, it was determined that:

- 9 eels crossed the dam out of the predicted migration date;
- 35 eels crossed the dam on the predicted date, without considering the time frame;
- 22 eels crossed the dam on the scheduled date and set time frame between 6 pm and 6 am.

The prediction model prepared anticipated 80% of the eel migration peak date, but only 50% of the eels crossed the dam within the assumed time frame between 6 pm and 6 am. However, it should be noted

Fig. 5. 2D telemetry network installed at CHG. Certain receiver positions have changed from 2017 and 2019: common items are in yellow, 2017 items are in red, and 2019 items are in green (Sonny et al. 2020).

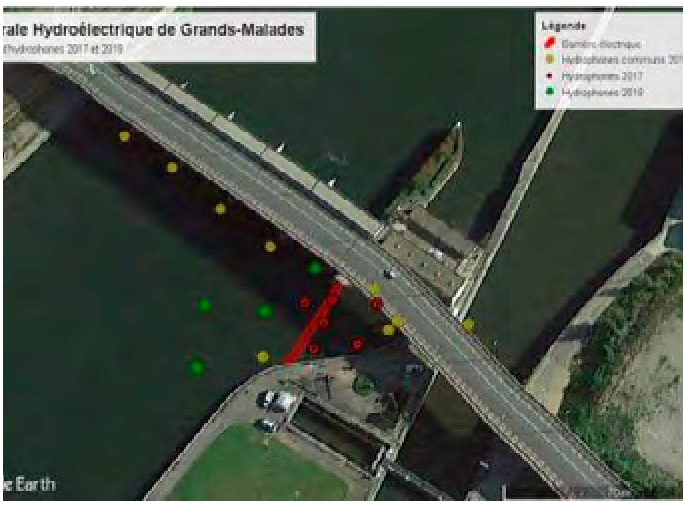
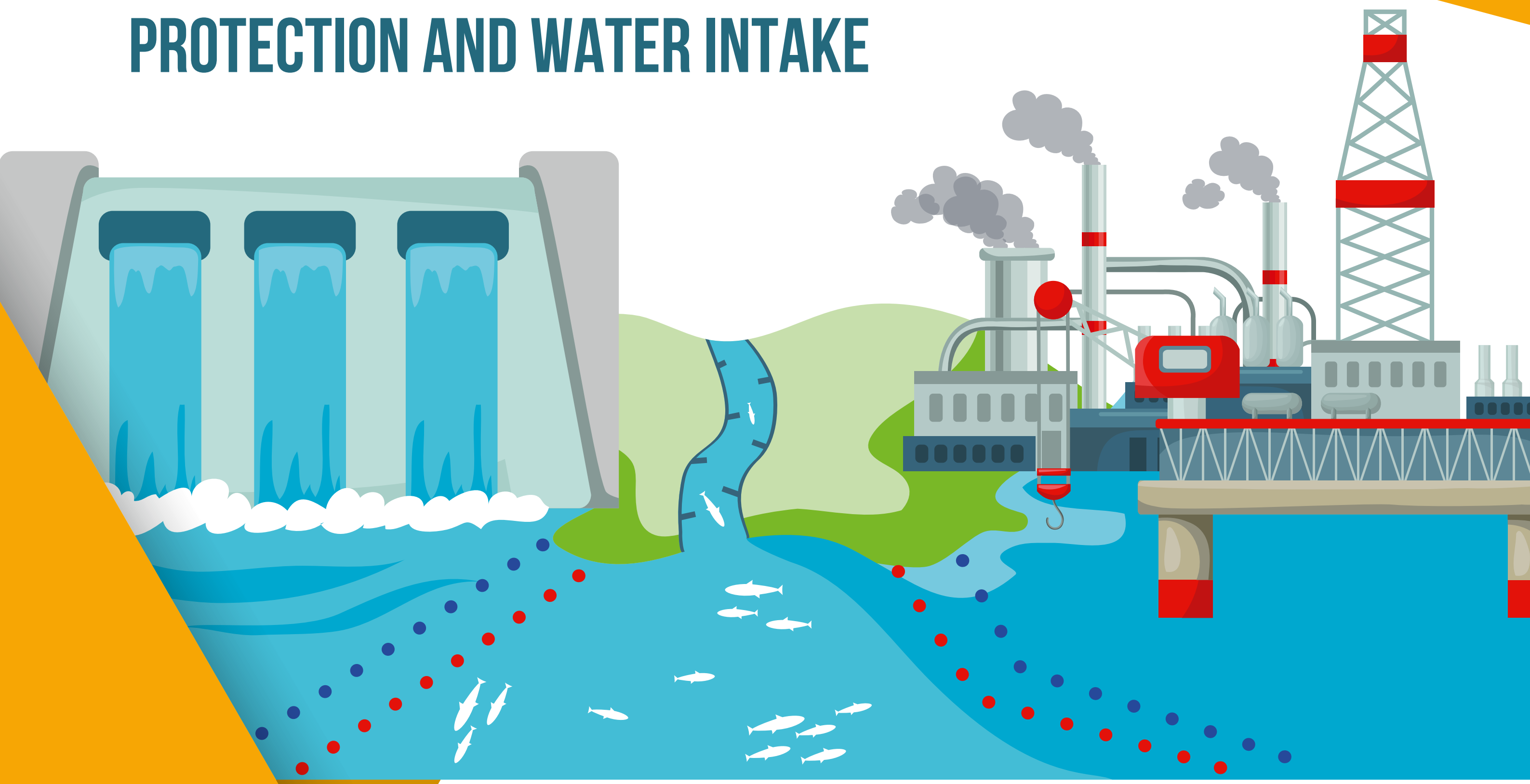


Fig. 6. 2D telemetry network at CHR. Certain receiver positions have changed from 2017 and 2019: common items are in yellow, 2017 items are in red and 2019 items are in green (Sonny et al. 2020).

neptun

EFFICIENCY IN THE NATURAL ENVIRONMENT 100%

INNOVATIVE TECHNOLOGY FOR FISH PROTECTION AND WATER INTAKE



Technology based on the method of producing increasing non-linear electric field intensity in the water environment

NEPTUN –
effective solution to deter fish from surface water intakes.
The system keeps fish away from exploring water engineering objects.
Its properties help protect fish and reduce maintenance costs of technological installations.

ADVANTAGES OF THE NEPTUN SYSTEM:

- High, nearly 100% efficiency in the environment proven by tests of independent units in the country and abroad
- A wide range of applications regardless of hydro-technological conditions
- Easy assembly in existing and brand new facilities
- High resistance to mechanical damage
- Low energy consumption

LAUREATE PROJECT

EKOODPOWIEDZIALNI W BIZNESIE

GREENEVO AKCELERATOR ZIELONYCH TECHNOLOGII

PROCOM SYSTEM S.A.
ul. Północna 15-19 bud. 2.2.
54-105 Wrocław

tel. +48 71 66 700
info@fishprotection.eu
www.fishprotection.eu

PROCOM SYSTEM

that in only 12 cases out of 32 alarms was the power station turbine successfully stopped within the timeframe mentioned above. Although the model could be further refined, operational implementation would require several legislative amendments and competency arrangements

c) Bubble barrier – Hydroelectric Power Station in Ivoz-Ramet (CHR)

The bubble barrier was commissioned on 12 September 2019, however, some adjustments had to be made, postponing the actual commissioning date to 20 September 2020. Despite the corrections made, the bubble barrier has not demonstrated hydrological resistance and has been declared non-functional as of 30 November 2019.

During this operational period, the installed antennas recorded a total of 15 marked silver eels passing through the CHR site. Among these fish, 12 eels were detected passing through the power station. Three eels were identified as possibly having passed through the power station, but their passage could not be confirmed as they were not detected by the other antennas below the barrier.

Therefore, the variable *Nbarrier (in)* was assumed to be 12 individuals. No eels passed through the dam. Following the assumptions established in the nomenclature, the effectiveness of the barrier was estimated as follows:

$$S^{barrier} = \frac{N^{barrier\ (out)}}{N^{barrier\ (in)}} = \frac{0}{12} = 0\%$$

Based on calculations, the bubble barrier demonstrated no obvious effect on increasing silver eel migration efficiency. It should be noted, however, that this finding is based on a considerably small sample. Furthermore, during the study period, the proportion of river flow through the power station varied between 79% and 92%. Under these types of hydraulic conditions, the potential for eels to overcome the dam is limited. Moreover, supplying compressed air to the installation required the use of an extremely large compressor, thus causing high electricity consumption and generating considerable noise levels deemed to be hazardous to humans.

SUMMARY

The telemetry study conducted on silver eels in 2019-2020 aimed to assess the effectiveness of protection and migration support of three different solutions installed on a pilot basis in three locations.

In the Grands-Malades area, the Neptune electric barrier managed to induce a significantly better migration rate through the dam compared to the 2017 reference situation of 30%. A quantitative analysis, based on the turbine entrainment ratio, assessed the barrier efficiency at 52%. Although this efficiency remains relatively low, however, considering that silver eels naturally migrate mostly through weirs in the Meuse River, it can be considered sufficient to be potentially applied to other locations during the full-scale implementation phase, which should occur in 2021.

At the Andenne site, 50% of the eels were within the predicted date and time range of 6 pm to 6 am as forecasted by the model. However, from a logistical perspective, decommissioning the turbine proved to be inefficient due to the complex coordination process with the dam operators, the necessity to implement regulations and due to the lost benefits from the cessation of electricity production. The performance of the model may be improved by extending the turbine standstill to 24 h at the migration dates predicted by the model.

A bubble curtain was implemented at the Ivoz-Ramet power station site. From a mechanical point of view, the barrier did not prove sufficiently resistant to a typical autumn flood, which would indicate that new tests would require improvements and reinstallation of the system. Furthermore, despite the limited data volume, no effect of the barrier on the behaviour of the eels was observed. For these reasons, the bubble barrier will not be subsequently tested on salmon smolts, and will probably not be selected in the LIFE4FISH project as one of the potentially available solutions.

The next phase of the LIFE4FISH project is to evaluate the balance between the costs of implementing individual solutions at the six hydroelectric power stations and the environmental benefits of implementing a global eel protection plan.

The Life4Fish Project

Luminus and its partners (UNamur, ULiège, Profish technologies, EDF R&D) received a grant from the European Commission in June 2017 to implement and validate different means of protection for two species of migratory fish in the Meuse, the silver eel and the smolt. The Life4Fish program was born. It aims to contribute to the protection of the two species through the sustainable exploitation of hydroelectric power plants.

The Meuse River lies in a natural environment of great ecological value but has suffered much degradation in the past due to high industrialization. Ambitious species restoration programs are in progress, targeting, among others, the Atlantic salmon (Salmo salar) and the European eel (Anguilla anguilla). In this context, the Life4Fish project aims at improving downstream fish migration along the 6 hydropower plants of the low Meuse River in Belgium. The project includes a characterization of the population and downstream migration routes of the two target species as well as the installation, implementation and monitoring of the impacts of innovative solutions designed to facilitate passage through the hydropower facilities. The solutions consist of individual technologies (repulsive barriers and fish passes) and new hydropower generation control strategies accounting for the intensity of the downstream migrating process.

Source: https://www.life4fish.be/en, https://www.uee.uliege.be/cms/c_4155203/en/uee-life4fish

M.Sc. Piotr Augustyn
PROCOM SYSTEM SA

Bibliography:

1. Olivier Machiels. 2020. DOWNSTREAM FISH MIGRATION ALONG THE LOW MEUSE RIVER – LIFE16 NAT/BE/000807 – Action C1 – Electrical Barrier Validation
2. Profish: Sonny, D., Beguin, J. & Lerquet, M. 2020. DOWNSTREAM FISH MIGRATION ALONG THE LOW MEUSE RIVER – LIFE16 NAT/BE/000807 – Action D2 – Monitoring of the effectiveness of the pilot solutions – Part I : silver eels.


renpro
ren
process
professional forecasting
projects
...and much more
We manage energy without a carbon footprint
Szczecin
phone/fax.: +48 91 812 15 32
e-mail: renpro@renpro.pl
Wrocław
phone: +48 516123925
e-mail: sprzedaz@renpro.pl
Grudziądz
phone: +48 517438174
e-mail: bok@renpro.pl
www.renpro.pl